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A

PRACTICAL TREATISE

ON THE

MANUFACTURE OF PAPER

IN ALL ITS BRANCHES.

BY

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ILLUSTRATED BY ONE HUNDRED AND TWENTY-NINE WOOD ENGRAVINGS, AND FIVE LARGE FOLDING PLATES.

PHILADELPHIA:
HENRY CAREY BAIRD,
INDUSTRIAL PUBLISHER,
406 WALNUT STREET.

LONDON: SAMPSON LOW, MARSTON, LOW, & SEARLE, CROWN BUILDINGS, 188 FLEET STREET.
1873.

SHERMAN & CO., PRINTERS, SEVENTH AND CHERRY STS.,
PHILADELPHIA.

PREFACE.

THE OBJECT of this book is to give a scientific and practical explanation of the different processes by which paper is made, to serve as a guide for those who desire to build mills, and to be a *helpmate* for paper-makers generally.

The facts and rules given therein are derived from experience, and especial care has been taken that the working-man may not look in vain for those practical details, which are often of more value to him than the most brilliant scientific explanations. The preparation of pulp from waste paper, as well as from straw, wood, and other vegetable fibres, has received the attention due to its importance.

The drawings represent machinery which is in active operation, built by first-class engineers, and of approved construction; they are carefully made in correct proportions, and many of them will serve for working plans in the machine-shop.

The consumption of paper, though it has increased enormously of late years, must still grow with the progress of civilization, and will in the future assume proportions, of which we can at the present time form no adequate idea. New raw materials are constantly required to satisfy these demands, and the processes of their transformation, which constitute the principal feature of modern paper-manufacture, cover already too large a field to be thoroughly mastered by one mind,—a fact, of which the author was fully conscious when he undertook this task. But, having acquainted himself with the theory of the art by studying the sciences which form its basis, and having acquired practical experience by the manufacture of fine and coarse papers from rags, waste paper, straw, &c., by the erection and management of four different mills in Germany and America, and by visits to hundreds of other ones in different countries, he determined to make the attempt.

As the following lines were gradually penned, their progress was frequently arrested by deficiencies in the author's knowledge, which could only be supplied from the experience of other paper-makers and machinists. For the purpose of obtaining the required information he called on the owners and managers of upwards of fifty of the prominent mills in this country, especially in New England; and he takes pleasure in testifying here to the almost universal kindness and liberality with which they permitted him to

investigate their operations, and freely communicated the results of many costly experiments and years of toil.

The author also gratefully acknowledges the kind and disinterested assistance rendered to him in the publication of this book by Mr. Henry Carey Baird.

The works of previous writers, and also the *Paper-Trade Journal*, published by Mr. Howard Lockwood at New York, the *Paper-Trade Reporter*, published by Mr. Champion Bissell at New York, and the *Centralblatt für Deutsche Papierfabrication*, published by Mr. C. A. Rudel at Dresden, have been largely drawn upon. If any quotations should have been made without stating the source, the indulgence of those whose mental property has thus been unintentionally appropriated is herewith solicited.

Perfection is not claimed for this work; it will probably be found deficient in many parts, and may be improved upon by future writers. If, however, it serves to advance the art of manufacturing paper by adding to the knowledge of those who follow it as their profession, the author's labors will not have been spent in vain.

C. H.

Philadelphia, March, 1873.

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A PRACTICAL TREATISE

ON THE

MANUFACTURE OF PAPER.

CHAPTER I.

PAPER.

THE WORD *paper* is derived from the Greek word *papyrus,* an Egyptian plant, which was used for writing purposes in ancient times.

Papyrus, parchment, wood, and stone, on which remote history has been transmitted to us, retained substantially their original form after they had been prepared for writing. To the Chinese belongs the credit of having been the first who formed from fibres the web which constitutes the paper of our time. Their raw materials are the inner bark of several trees such as the mulberry, and the bamboo, rags, rice-straw, and others. The infinite variety of uses to which paper is put in China, as articles of clothing, handkerchiefs, napkins, twine, furniture, &c., shows the state of perfection which its manufacture has there reached.

The Chinese consider paper so indispensable that a certain quantity is frequently secured to their wives in their marriage contracts.

The knowledge of the art seems to have been communicated by the Chinese to the Hindoos and Arabs, brought by the latter to Spain during their occupation of that country, and from there it found its way to all parts of Europe.

Paper made from cotton, with authentic dates from the tenth and earlier centuries, is preserved; but linen paper cannot be traced further back than the thirteenth century, from which time it seems to have taken the lead. From that period up to the end of the eighteenth century paper was made in Europe almost altogether from rags.

Paper, at the present day, is made from such an infinite number of materials that it would hardly be possible to enumerate them all. They are, however, all directly or indirectly of vegetable produce, such as flax, hemp, cotton, wood, straw, esparto and manilla grasses, jute, cane, &c., and the art of paper-making consists in the reduction of all these materials into their primitive fibres, and forming them into felted sheets.

Flax, hemp, and cotton are reduced to a very small proportion of their original bulk by the time they leave the weaving-mills, and nothing but the clean fibres are contained in the goods made from them.

Considering that out of a hundred pounds of flax or hemp, as it comes from the soil, only about two and a half pounds of good white linen are obtained, and only a portion of it (the best part of the whole) finds its way into the paper-mill, it seems certainly a vain attempt to look for any produce of the vegetable kingdom which, in its original form, can furnish either an equal proportionate quantity or quality of fibres as the same weight of rags.

The consumption of paper has, within the last fifty years, increased at a much greater rate than the supply of rags; the price of the latter having consequently begun to rise, has made it possible to bring other raw materials into competition with them for the lower grades of paper.

The perfection of the art has also enabled the mills to make better paper from inferior rags, and their place has gradually been filled up by new fibrous substances.

It is neither necessary nor desirable to make the best qualities of paper from anything else but rags, but they have to be reserved for them alone.

Education, assisted by the printing press, is becoming more universal than ever before, and the constantly increasing demands of civilized humanity on the paper-mill can only be met by a corresponding production of pulp from new materials or substitutes. With the aid of science this is being done. The manufacture of straw, wood and esparto pulp has been so improved that the bulk of the news- and cheap book-papers is already made of these materials.

The grades of paper for which rags will be used are thus gradually reduced in number; but the fact of their stricter exclusion from the large army of common papers, only confirms the opinion of those paper-makers who are often heard to exclaim, in utter contempt of straw, wood, and other substitutes:

"Rags are yet King!"

We may add that they will probably always remain king, if that dignity depends on their permanent superiority over all other substances as the material for the best and most valuable kinds of paper.

We shall, therefore, treat first of rags, and in later chapters of the substitutes.

CHAPTER II.

MANUFACTURE OF PAPER BY HAND.

DURING THE eighteenth and the beginning of this century linen and cotton rags were sorted only at the mill, and principally according to color.

Chlorine and its use for bleaching had not yet been discovered, and the color of the rags determined that of the paper.

They were then cut into small pieces, soaked in water, and piled up in this moist state in cellars or vaults, in order to produce fermentation or, as it was called, to make them rot.

The rotting process lasted from six to twenty days, and during that time the rags had to be frequently turned, to avoid overheating and to treat the whole mass uniformly. The vegetable gluten which gives to the rags a certain stiffness, and the fatty and coloring matters, underwent, during this operation, a chemical transformation similar to the putrefaction of decaying plants, which is constantly carried on by nature on a gigantic scale.

The same process which destroyed the gluten, fat, &c., attacked also the fibres if not arrested in time, and it required considerable experience and attention to conduct it to the best advantage.

The rags were then washed in large quantities of water, and put in rows of wooden or stone mortars or upright cylinders, wherein close-fitting stampers went up and down, moved by a water-wheel, shaft, and levers. A small stream of water, entering at the top and passing through holes in the bottom, kept up the washing process all the time. The pounding was continued until a perfect disintegration or transformation into pulp had taken place.

No cutting or tearing instrument having been used, the fibres were obtained of full length; and this is certainly one of the causes why the papers of that period show such extraordinary strength.

This pounding process, although perfect in principle, was so cumbrous and slow that it was quickly abandoned when *the Hollander* made its appearance.

In the middle of the eighteenth century the beating-engine, in its main features precisely like those used at the present day, was invented by the Dutch or Hollanders, and with it a new impetus was given to paper-making.

It is certainly a just tribute to the genius of the unknown inventor and to his country that the Germans yet eall the engine *the Hollander*, in honor of his nationality.

After the rags were washed and beaten in this engine, in the same manner as we now do, the pulp was emptied, with a large quantity of water, into an open vat. The paper-maker stood alongside of this vat, and dipped a wooden frame covered with wire-cloth into it, taking therewith, by a clever movement, enough pulp to form a sheet of sueh thickness as he wanted. While the water was dropping through the wire, he shook the frame in all directions to make the fibres intertwine and felt themselves, thereby forming a compact sheet of paper.

The size of the sheet was determined by *the deckels*, which formed an elevated border all around it. Their adjustment, as well as the whole operation of making the sheet, required great skill; the paper-makers of old had therefore just cause to be proud of their trade, as everything depended on their ability and judgment.

The deckels were then taken from the mould, and the latter was given to the coucher, who took the sheet off and stretched it on a felt. A post of these felts, in which they alternated with the paper-sheets between them, was subjected to a strong pressure in a hydraulic or other kind of press, for the purpose of forcing the water out. After some time the post was removed, and the sheets were laid between other felts in the same way, pressure was again applied, and the operation repeated until the paper had acquired consistency enough to be sized, or to be directly carried to the drying-loft. The sizing and drying were done on the same principles and substantially in the same manner as now practiced, and described in a subsequent chapter.

This system of making paper by hand has been entirely abandoned in the United States, even the finest of bank-note paper being manufactured on the maehine. It will soon be everywhere merely a matter of history, and we have therefore contented ourselves with giving only the outlines of it. Most of the older books on paper-making may be referred to for more detailed information.

Though we are doing with maehinery what was formerly accomplished slowly by hand, the prineiples which guide us are yet the same. Every part of the process just described is carricd out in our modern mills, although modified under the guidance of science and assisted by improved machinery.

Chapter III.

MANUFACTURE OF PAPER FROM RAGS BY MACHINERY.

WE DIVIDE the making of paper from rags into the following distinct operations:

Section 1. Sorting, Cutting, and Dusting.
Section 2. Boiling.
Section 3. (*a*) Washing, (*b*) Bleaching, (*c*) Draining, (*d*) Bleaching with Gas.
Section 4. (*a*) Mixing, (*b*) Washing and Beating, (*c*) Sizing, (*d*) Coloring, (*e*) Patent Engines, (*f*) Stuff-chests and Stuff-pumps.
Section 5. Paper Machines: (*a*) The Fourdrinier Paper Machine, (*b*) The Cylinder Machine, (*c*) Harper's Improved Machine.
Section 6. Surface Sizing.
Section 7. Finishing.

SECTION I.

Sorting, Cutting, and Dusting.

1. **Purchase.**—The rags are received at the mill either mixed or already roughly sorted.

No matter how they are purchased, great care must be taken that the article bought is really received. There is probably no trade in which more tricks to cheat the buyer are practiced than in the rag trade.

Bales are sometimes made up looking well outside, and containing an inferior article inside.

Water is sprinkled on the rags, and we have even seen sand put into them to increase their weight. Rags have always a natural humidity, which may vary from five per cent. in fine rags to seven or eight in coarse ones, but no more than that should be allowed. In doubtful cases, it is advisable to dry a lot by spreading them out in a warm room or exposed to the sun. The difference between their wet and dry weight gives the quantity of moisture contained in them.

Experience and careful examination soon teach how to detect and avoid dishonest dealers, and enough may be found who believe in the axiom that "Honesty is the best policy."

Color and strength of material mainly determine the value; and it is a strange fact, that the different countries produce rags so entirely different in character that experienced men are often able to tell, after an examination, where they come from.

Some countries have a cold, others a hot climate, and the people need a heavier or a lighter dress accordingly. Some nations wear more linen, others more cotton; some coarser, some finer. City rags are easily distinguished from country rags, the former being fine and white, the latter coarser and darker.

2. Thrashing.—All rags have considerable quantities of dust, sand, and other impurities mechanically mixed with them, and it is very desirable that they should be purified as much as possible before undergoing the subsequent wet treatments of boiling and bleaching. Formerly the rags were invariably first assorted, cut, and then put through dusting machines. Consequently an atmosphere of dust prevailed very generally in the sorting-rooms, which was not only disagreeable to the sight, but injurious to the health of the employees.

Fig. 1.

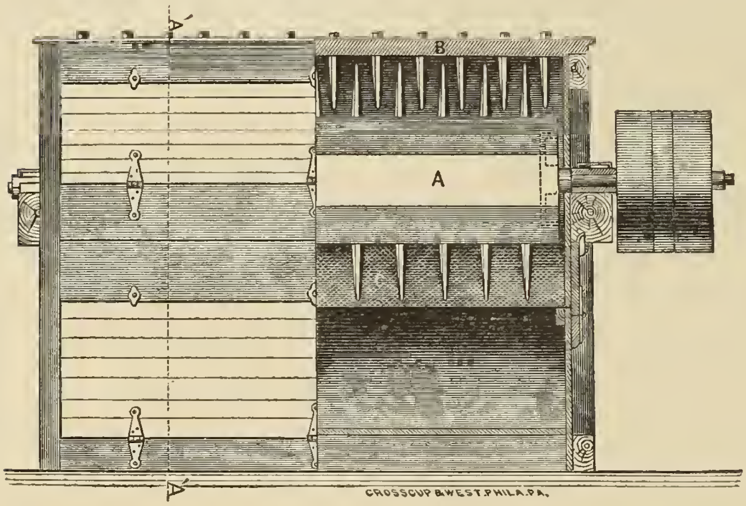
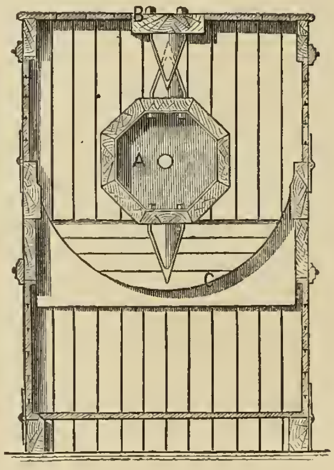


Fig. 2.



It has now become a rule in many mills in this country to put the rags, as soon as they are taken from the bales, into a dusting machine or thrasher, which frees them from most of the adhering dust, and makes them less objectionable to the sorters. Fig. 1 is a section lengthway, and Fig. 2 a section through 'A-'A of Fig. 1, representing a thrasher of $\frac{1}{32}$ of the real size.

It consists of a wooden eight-cornered body A, on an iron shaft, revolving inside of a light wooden box, and driven by means of belts and pulleys outside. In this box, above and parallel with the shaft, one row of teeth is fastened to a strong timber B; the revolving cylinder carries a corresponding number of teeth in straight lines.

A few inches below the circle described by the points of the revolving teeth, a bottom of perforated iron or wire C, bent in a concentric circle, is fastened to the box.

The rags are filled in through a door of the same length as the box fastened with hinges above the upper edge of the circular bottom, and they are discharged through a similar door on the opposite side.

As soon as the thrasher is loaded, the doors are closed, the pulley is started, and the revolving teeth carry the rags up and through the stationary ones, constantly beating or thrashing them violently.

Both sets of teeth must be constructed substantially to sustain these hard knocks without breaking or bending. Fig. 3 is a view, and Fig. 4 a section through

FIG. 3.

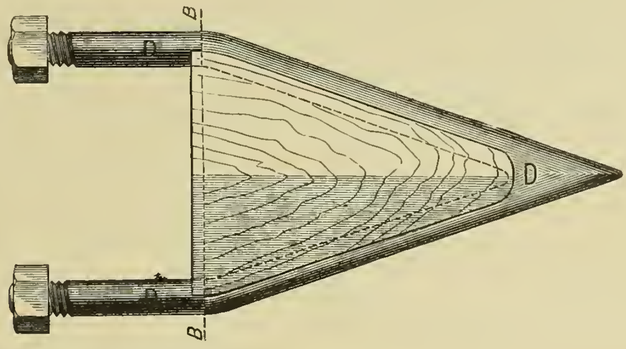
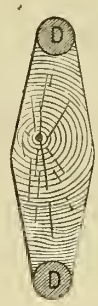


FIG. 4.



B-B of Fig. 3, showing a tooth of one-quarter of the real size. It consists of a strong iron bolt D, bent and formed to a point. The bolts D go through the whole body of the timber; they are fastened with nuts on the opposite side, and wood is filled into the sharp triangle, to increase their strength.

A bottom constructed of light material would soon be torn to pieces. If wire is used, it should be of $\frac{1}{16}$ to $\frac{1}{8}$ inch iron and No. 3 or 4 web. Sheet-iron plates, even if perforated all over, do not offer so much open space for the escape of grit and dust as wire. We have also seen one of these bottoms composed of $\frac{1}{4}$ inch flat iron, standing on edge and bent into half-circles, set in wood, $\frac{1}{4}$ inch apart from one another, with wooden keys in three or four places to keep them separate. This construction certainly furnishes a strong bottom, but it makes it possible for whole rags to escape crossways through the bars.

A change of the speed moderates or increases the thrashing in the same proportion. Sometimes it may be desired to intensify the operation by reversing the motion; and this can be done by means of one tight pulley flanked by two loose ones, and operated by open and cross belts.

The dust gathers in the lower part of the box, and may be removed from there through doors.

The objection to dusters, that they waste much fibre, may be well founded for rags which have been cut into small pieces, offering all around short, open threads, which may be torn off by friction; but whole rags will certainly stand a much more violent beating without injury. It may even be found that the thrashing before cutting will effect as much, and cause less loss than a gentle dusting of the rags in small pieces.

The thrasher is to be located either on the same floor with the sorting-room or on the next one above, so that the rags can be thrown down through the floor.

This one, as well as all other dusters and cutters, should be in a room other than the sorting and store-rooms, to prevent the dust, which, notwithstanding all precautions, escapes sometimes, from settling again on the rags.

In some mills ordinary dusters are used instead of the thrasher, but, as the rags go through them more rapidly, they cannot be expected to give as good results.

3. **Sorting and Cutting by Hand.**—The assortment of rags has to be suited to the particular circumstances of the mill. Every country, nearly every paper-maker, has a different one; but all of them make the following distinctions:

They divide

According to fibre, ...	Linen, Hemp, Cotton, Manilla, Half-wool or woollens.
According to color, ...	White, first, second, third; Gray, " " " Blue, Red, Black, containing all dark colors.

Canvas, ropes, bagging, twine, threads, and others are also classed separately.

If a mill is making a great variety of papers, a large assortment of all the different grades of rags has to be kept on hand; but, if judicious management has reduced the produce to a few—or better, to only one—kind of paper, only such rags will be purchased as can be used for it, and, though it may be a convenience, a large stock is not necessary.

Dealers generally sort the rags so that none or little need be purchased which cannot be used for the class of paper made at the mill. If mixed country-rags are purchased, the qualities which are not wanted can be sorted out and sold to other manufacturers or to dealers.

At a mill where only one grade of fine book-paper is made, we have seen all the rags, no matter of what color or fibre, worked together. Soft cotton, strong linen, and colored rags are thus exposed to the same boiling, beating, and bleaching. These operations must be carried on far enough to produce white pulp from the

coarsest fibres, and the strong chemical and mechanical treatment, which is necessary to do this, probably damages and destroys some of the finer and softer ones.

We believe this to be a wasteful system, and would advise making at least enough grades of rags to enable the separation of the strong from the weak, and the white from the colored ones, so that each fibre may receive the treatment it requires without being exposed to that of its perhaps much stouter neighbor.

No matter how many qualities are made, the rags are invariably given to the sorters after having been thrashed. The women doing this work stand before a square or oblong table, covered with coarse wire cloth, and surrounded by enough square boxes, baskets, or bags to provide one for every grade of rags which is to be sorted out.

The handiest boxes, which we have seen at Holyoke, consist of high square baskets, made of split wood, and standing on four small iron wheels, on which they can easily be pushed to any part of the room.

A knife of scythe shape is fastened to each table, standing upright, with the thick back against the worker. It serves to cut the rags as well as to separate from them seams, buttons, buckles, leather, rubber, and other foreign substances.

The labor of cutting the rags is in this country performed by machinery for all kinds of paper except the best qualities of book and writing paper. Very fine and high-priced rags are exclusively used for the latter, and it is believed that a smaller proportion is wasted if they are cut by hand. The machine, of course, cannot hit the rags exactly on the line of the warp or woof, and the threads, if cut obliquely, are certainly more apt to be lost in the subsequent operations of dusting, &c. The knives of most cutting-machines sometimes tear the rags instead of cutting them, especially if they are not very sharp, and a part of the threads thus torn is invariably lost. If cut by hand the rags remain a longer time in the hands of the operative, who can, while cutting them length and crosswise, discover impurities which had escaped her observation until then.

There can be no doubt of the superiority of cutting by hand over that by machine, and the price of labor alone can decide where the one is to begin and the other to stop.

It is hardly possible to establish a rule for the sizes into which rags ought to be cut, as those of weak material should be left in large pieces, while strong ones may be cut much smaller. The usual length and width vary from two to five inches.

The assorted rags, cut or uncut, should be passed in review on a large table by the overseer of this department, not so much to improve them as to control the work of the women.

It is well known, and we only state it here as a matter of record, that rags, piled up in a wet or damp state, being then in the same conditions as if prepared for the rotting process, will become heated. Such rags are to be carefully kept out of the mill, or turned and aired frequently if their presence cannot be avoided. Spontaneous combustion resulting from this cause has kindled many a destructive fire.

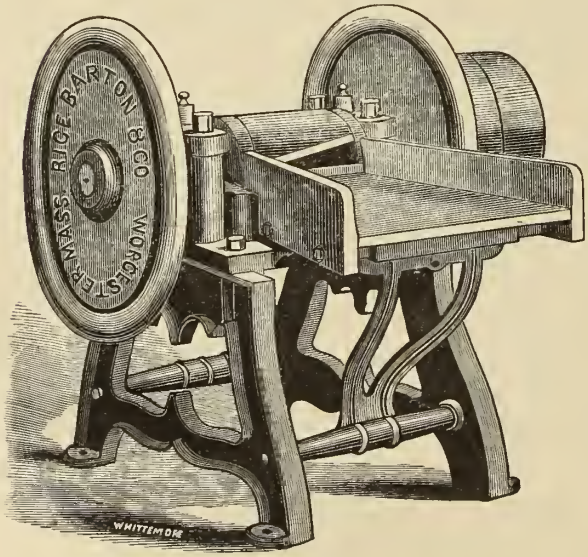
4. Rag Cutters.—All rag cutters may be compared to scissors on a large scale. The stationary part, the bed-knife, presents a sharp edge to the moving part or cutting-knife, and the various systems of rag cutters differ principally in the construction by which the movement of the latter is produced. The main features of the construction of several cutters are explained in the following lines; but a detailed description is given of those only which have stood successfully the test of time:

The driving shaft of a cutter, not frequently seen, is fastened alongside of and parallel with the feed-box, and carries on its forward end a wheel, the arms of which consist of curved knives, each of which passes the bed-knife at every revolution, and makes a cut.

Another cutter works with a straight up and down movement, like a guillotine, the movement being produced by cranks or eccentrics. The principle of this cutter is certainly correct, as it tears the rags less than any other one, and cuts without difficulty the finest cotton and the heaviest rope. All cutters of this kind, which have heretofore been offered to the trade, have, however, been deficient principally because they could not be made to perform as much work in the same time as the revolving cutters. The time used in a guillotine-cutter for the upward movement is lost, while revolving knives cut without intermission.

There is a very substantial class of cutters of great capacity which have a solid cast-iron cylinder of about eight to twelve inches diameter, carrying two or three knives. The shaft of this cylinder is placed parallel and in the same horizontal line with the bed-knife. The revolving knives are bolted to it in such a way that, while one end strikes the bed-knife, the other one is yet about two inches distant, thereby producing the gradual cutting of shears.

Fig. 5.



All the power is consumed while the knives are in contact, and none is used in the intervals; the motion would therefore be a hacking one if some regulator were not applied. One or two of those reservoirs of power, called fly-wheels, are therefore placed on the revolving shaft, and should be large and heavy.

These cutters require for strong rags several horse-power, and, if not very solid, will soon give way in some part. The one pictured in Fig. 5, built by Rice, Barton & Fales, Worcester, Massachusetts, is entirely of iron, and probably for this reason as much as for its simplicity, a favorite with our paper-makers. From personal observation we can state that the large majority of rag cutters in this country are constructed on this principle.

The rags are mostly fed to the cutter by hand, and frequently the hands are caught by the knives and mutilated. Feed rolls are often added to prevent this. The channels of the fluted cylindric rolls, which are sometimes used, soon become filled up, and are thrown out as useless.

The cutter shown in Fig. 6 is provided with a cast-iron feed-roll A of about 4 to 5 inches diameter, the surface of which is covered with small cones of about $\frac{1}{2}$ to 1 inch diameter at the base, and $\frac{1}{2}$ to 1 inch high, each one of which acts as a finger in holding, and, by its revolving motion, pushing the rags. The surface of this roll cannot easily be filled up, and it deserves to be recommended as a safeguard for the operator.

Fig. 6 is a section through the middle of a cutter, of $\frac{1}{24}$ of the real size, or $\frac{1}{2}$ inch

Fig. 6.

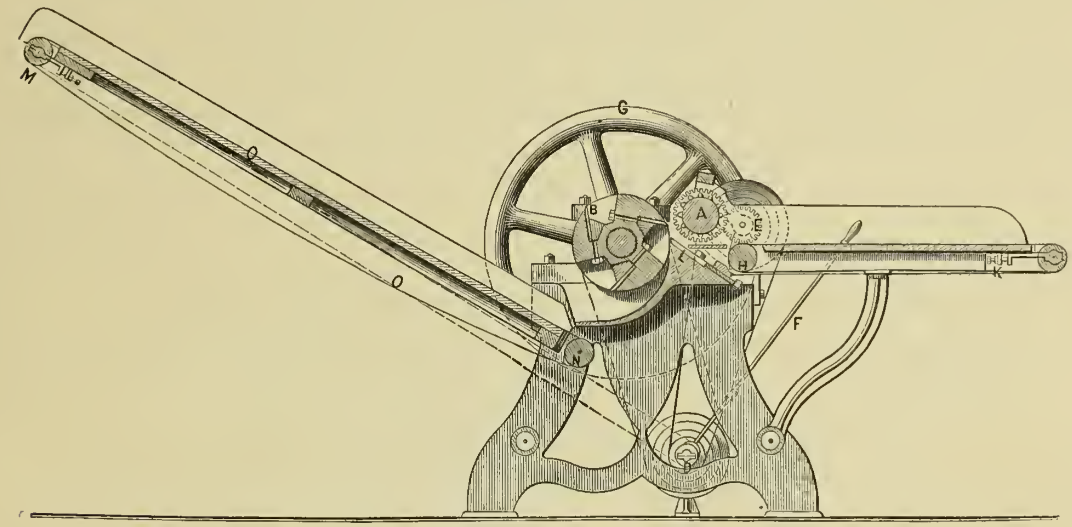


Fig. 7.

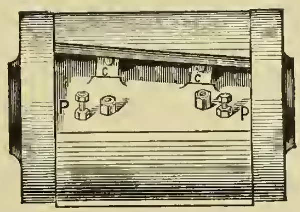
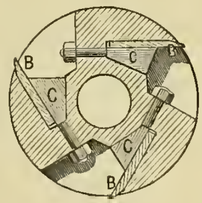


Fig. 8.



per foot, and Figs. 7 and 8 show the revolving knives alone, in view and section, of $\frac{1}{12}$ of the real size, or 1 inch per foot.

The revolving knives B B B are of cast-iron, held in their positions by two keys C, without any other fastening. The keys C end in bolts which can be drawn up by a nut. These cast-iron knives require no sharpening, being in such a position that they form sharp angles with the outside circle, on which they wear off, and thus

retain a sharp edge all the time. Two set-screws P P bear on the back end of each knife B, and whenever it has been worn off so that it becomes necessary to move it out, the keys C are loosened and the knives pushed forward by means of P P. We know of a mill, where one set of such cast-iron knives has served for years, and is yet in as good order as ever.

Shaft D is driven by a belt, and can be put in and out of gear by the lever F. It drives in its turn the shaft of the revolving knives and the shaft E, which moves the feed-apron and roll.

The revolving knives are running with the same speed all the time, but the speed with which the rags are fed varies with the length into which they are to be cut. The slower the rags are pushed in, the longer are they exposed to the action of the knives, and the shorter will they be cut.

The shafts D and E are therefore supplied with corresponding sets of pulleys of different sizes, by means of which the speed of E can be changed.

The feed-roll A rests in two levers, which turn on shaft E, and are connected by a crosspiece above A. A spurwheel on E drives another one on the feed-roll shaft, and the relative positions of these wheels are not altered by any change in the position of A. The feed-roll is free to rise up and make room for any thick package of rags, and retains all the time its revolving motion. The shaft of the revolving knives carries a flywheel G, and the apron which feeds the rags to the roll A is supported at the ends by the rolls H and I. Roll H is driven from shaft E by a belt, and the apron may be stretched by moving out the roll I by means of the screw K.

The bed-knife L is of steel, fastened on a cast-iron body, and can be set up against the revolving knives by two set-screws, which bear on its back end.

The apron O, running in a box and over the rolls M and N, receives the cut rags, and delivers them at any desired point. M is a stretch-roll, which may be moved in or out by means of a screw at each end; it is also driven from D by a belt, and communicates its motion to the apron.

This cutter makes one hundred or more revolutions per minute, and requires a strong foundation. Being usually situated in one of the upper stories, if not the highest story of the mill, it should be supported by heavy timbers resting on strong walls and pillars.

Stump knives of any kind invariably tear the rags instead of cutting them, require more power, accomplish less, and cause much more waste than sharp ones.

If the cutter is not constructed so that the knives sharpen themselves while wearing down, several sets must be kept on hand, frequently exchanged, and sharpened on a grindstone.

Attempts have been made to construct a machine which would cut the rags both length and crosswise in one operation, but so far, like many other complicated devices, they cannot compete with the simpler ones.

To facilitate the work of the engines, it is desirable that coarse, strong rags should be cut into small pieces, and for this purpose they are frequently passed two

or three times through the cutter. To avoid this double operation, some mills use two cutters, one behind the other, connected by an apron carrying the rags from the outlet of one to the feed-table of the other cutter. We would, however, suggest that two cutters, if used together, should be disposed at right angles against each other, so that the rags which have been cut lengthwise on the first cutter will be carried by the aprons in the same position to the second one, and there receive a cross cut.

Rag cutters fill the room in which they are being worked with dust, and to avoid this they are frequently provided with caps, similar to those covering the roll of an engine, and connected by wooden spouts with a ventilator, drawing the dust and air from the top of the cover. One ventilator is sufficient for several rag cutters, and not only abates a nuisance, but collects the dust, a material of some value for lower grades of paper, which would otherwise be lost.

From the cutter the rags go directly to the duster, where they are to be freed from sand, straw, metals, and other foreign substances.

5. **Rag Dusters.**—I. The following Fig. 9 represents a section lengthway through the box, and Fig. 10 a view of the feed end, of one of the most generally used rag dusters, at about $\frac{1}{64}$ of real size, or $\frac{3}{8}$ inch per foot.

Fig. 9.

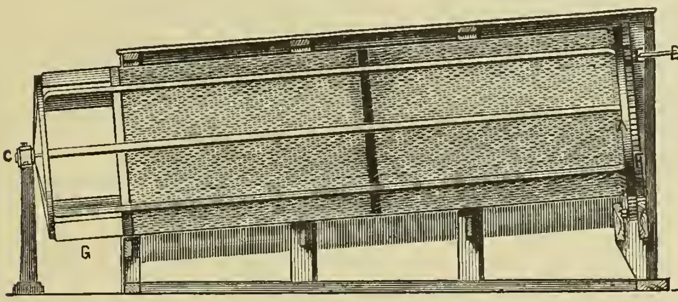
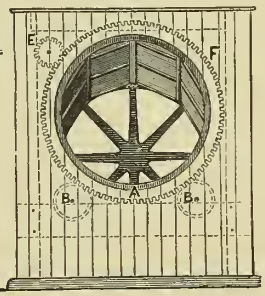


Fig. 10.



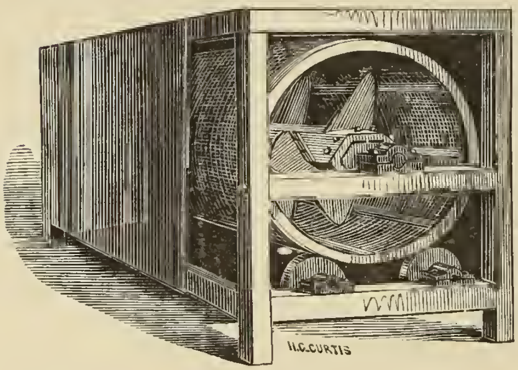
This duster is eight-cornered, rests at the lower end in the stand C, and carries at the upper end a cast-iron ring A, supported by the two flanged pulleys B B. It is set in motion by the shaft D, and pinion E, which latter turns the spurwheel F. The duster is covered with coarse No. 3 or 4 wire netting, as far as it is inclosed in the wooden box. The rags enter at the higher end, and descend gradually, while revolving, to the lower open end G, where they fall out. The dust and impurities, which pass through the wire, collect on the bottom below, and can be removed through side doors.

These dusters have sometimes three or four cast-iron rings or tires like A, extend only as far as the box, and have no stand and bearing C. They are then supported, directly under the centre-line by one flanged roller, like B, for every iron ring. A long shaft, driven by a belt and pulley outside, carries all these rollers and

revolves the duster by the friction on them. The rings, being supported only at one point, must be held in their position by two little iron rollers, one on each side, fastened to the frame of the casing.

II. *Holyoke Duster.*—The dusters are often provided with a centre-shaft, studded with spokes or pins, and turning in a direction opposite to that of the wire. The pins are set in a spiral line, pushing the rags forward while brushing them against the netting.

Fig. 11.



In many fine New England mills the centre-shaft carries sheet-iron spiral-shaped wings, instead of pins. The cylinders are placed horizontally, as the rags are pushed through, and require no fall. The inside shaft and a shaft carrying one of the sets of rollers, on which the cylinder rests, are driven by separate belts. Fig. 11 shows one of these dusters, as made by Messrs. Pattee & Fairchild, in Holyoke, Mass.

III. *Devil, or Picker.*—If coarse or very dirty rags are used, it is desirable to give them a more violent shaking than they can receive in ordinary dusters, and then a devil is called on for assistance. In the devil the axe alone is moving, and carries a wooden cone of 4 to 6 feet length, and 6 to 8 inches diameter at one, and 9 to 12 inches diameter at the other end. This cone is dotted in a spiral line with iron pins, firmly bolted all through the wood. The author has used such a cone, with pins screwed into the wood only three to four inches deep, but it was not very long before most of them were loose and torn out. None but the strongest fastenings, similar to those shown in Figs. 3 and 4, will answer. The circular cover of this devil is composed of heavy (3 to 4 inch) planks, bolted on to cast-iron ends. To the uppermost of these planks a row of pins, like those on the cone, is bolted in the same manner as to B in Fig. 1, and disposed so that the revolving pins may pass between them.

The bottom is also circular and of strong wire netting or perforated sheet iron, through the holes of which a good deal of dirt and dust falls into a space underneath, left for that purpose. The rags are fed in on top at the smaller end of the cone, and come out shattered and torn at the larger end.

The difference between this devil and the thrasher is only that the revolving centre-piece of the former is a cone, and that of the latter a cylinder; that the teeth or pins are set in a spiral line on the cone; that the casing is circular; and that the rags are fed continuously to the devil, and only at intervals to the thrasher.

The devil runs with about 200 to 400 revolutions, while ordinary dusters, like those shown in Figs. 9, 10, and 11, have a moderate speed of about 30 turns per minute.

IV. *Railroad Duster.*—Within the past few years the so-called railroad dusters have frequently taken the place of devils. Fig. 12 shows one of them, in front elevation, partly in section, and Fig. 13 as seen from above, with the covers partly removed. It is drawn on a scale of $\frac{3}{8}$ inch per foot, or $\frac{1}{32}$ of the real size.

Fig. 12.

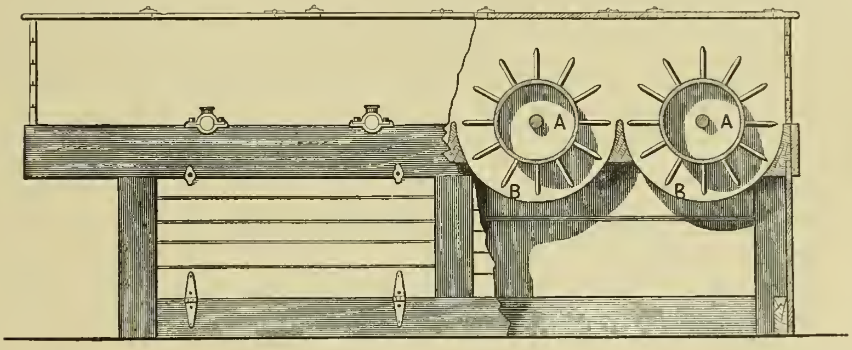
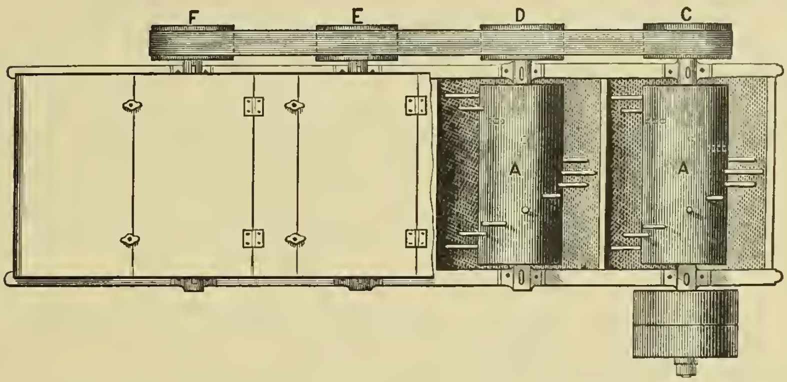


Fig. 13.



The cylinders A, are of cast iron, and their number, like the cars of a train, is hardly limited.

The wrought-iron pins are set in spiral lines, so that the rags are not only pushed forward over the bottom, but also move sideways. The bottom B, is again formed of coarse wire netting or perforated sheet iron, and follows the course of the pins. The pulleys C and D are connected by a belt, and E and F by another one, while one common belt envelops both of these belts and all the pulleys, C, D, E, and F. A pulley on the shaft of pulley C thus puts all the cylinders in motion.

The rags are fed in through an opening in the cover at one end, and the cylinders forward them from one to another over the bottom B, until they fall out at the other end. The cylinders make about 150 revolutions per minute.

The covers are held down by washers, and can easily be turned up on hinges to remove obstructions on the teeth or cylinders.

For convenience, as well as quick and efficient work, this duster is preferred to all others by those who use it.

6. Use of Dusters.—In many mills the cut rags are passed through several dusters; as, for instance, first through a devil or a railroad duster, and then through an open cylinder or a Holyoke duster. For fine cut rags the latter alone is generally considered sufficient. In some carefully managed mills, the dust from white rags is again passed through the duster, and many small pieces of rags and threads are thereby saved. It would probably pay very well for large mills to have a duster for the sole purpose of passing through it the dust from all the other ones.

7. Aprons.—The rags after having been fed to the cutter ought to pass from there, without any assistance, through additional cutters, devils, and dusters, until they fall on the floor above the boiler or directly into it. They are transported from one of these machines to the next one, sometimes far off, by aprons, such as shown in Fig. 6. An open box, 6 to 20 inches wide, with stationary sides and movable bottom, represents an apron. The movable bottom O, or the apron proper, consists mostly of strong canvas supported by a board or several light rolls, and two larger rolls, M and N on the turning points. The ends are sewed together, while the apron is spread around the rolls, and it is thus made endless. One of the larger rolls M is driven by a belt and pulley, and in its turn moves the apron. A stretch-roll M, by which the apron can be kept in the proper state of tension, is also necessary.

The rags falling on such an apron are carried off in the direction in which it moves, horizontally or upwards in an incline, and fall at the end either on another apron, perhaps at right angles to the first one, or into another machine.

Sometimes strips of wood are fastened across the apron, but they are not necessary.

Some aprons are composed of two narrow leather belts, across and on which strips of wood, about one inch wide and $\frac{1}{2}$ inch thick, are riveted, thus forming a wooden apron. The strips are only about $\frac{1}{4}$ inch apart, not enough to allow rags to fall through between them.

8. Waste from Cutting and Dusting.—Good foundations and tightly-closing boxes, to prevent the dust as much as possible from escaping, are required for all dusters.

Every operation in the process of transforming rags into paper causes a loss of fibres, and it is therefore desirable to avoid as many of them as possible. Fine paper cannot, however, be made, especially from inferior rags, without a thorough process of cleaning, and in that case, where the better quality fully makes up for the losses incurred, too much attention cannot be given to the sorting and dusting. For lower grades of paper some of these operations may be omitted, and the first cost, labor, and waste, which they involve, saved.

The loss suffered by the rags from cutting and dusting can hardly be estimated, as it depends on the raw material, the number and nature of the machines used, and their management.

Proteaux, in his *Practical Guide for the Manufacture of Paper and Boards*, gives, however, the following figures for the waste of rags by sorting, cutting, and dusting:

Whites, fine and half fine,	6 to 9 per cent.
" coarse,	10 to 15 "
Cottons, white,	6 to 10 "
" colored,	10 to 13 "
Pack cloths and coarse threads containing straw,	15 to 20 "
Ropes, not of hemp,	16 to 18 "
Hempen ropes containing much straw,	18 to 22 "

Though our manufacturers may obtain different results from their rags, these figures give a good idea of the proportion in which the different qualities lose under the same treatment.

SECTION II.

Boiling.

9. Washing.—The rags, after having been cut and dusted, are in some mills subjected to a washing process in a machine which resembles a cylinder duster, immersed in a cistern, with a constant stream running through it.

This wet duster may be dispensed with if the boiling and subsequent washing are carried on in a thorough manner. We have not found one of them in the numerous mills which we have visited in this country.

10. Boiling in Tubs.—The rotting process of old has been entirely superseded by boiling with alkalies.

Stationary wooden or iron tubs used to be employed altogether for this purpose. They are in some mills, even at this day, preferred to rotaries, and constructed substantially like the tubs used for boiling waste-paper (see Chapter IV, Section III). The rags are carried by a perforated false bottom, below which steam is introduced through an open pipe or coil; and the liquor, being thus heated, boils up in the centre-pipe, and is spread uniformly over the rags by means of the bonnet. It percolates through the rags, collects again below, and recommences the same circulation. The liquor is a solution of soda ash, caustic soda, or lime in water.

After the rags have been boiled for ten to twenty hours the entrance of steam is stopped, the liquid drawn off, the lid removed, and the rags are thrown out with forks or other tools operated by hand.

This operation offers several serious difficulties. It is very difficult to boil the rags uniformly, because the liquor may descend more freely in one place, depriving the rest of their share; there is a constant loss of steam through the imperfectly closing

covers, and the emptying of the boiled rags is very hard and disagreeable work, unless a hoisting apparatus is provided for it.

11. Rotary Boilers.—Rotary boilers are not liable to these objections, and have very generally gained the ascendency. The devices for their construction are very numerous; but few have stood the test of time, and we content ourselves therefore with the discussion of the one which is used in most of our mills.

It is a wrought-iron cylinder of from 10 to 25 feet in length, and from 6 to 8 feet diameter, with cast-iron heads ending in journals, as represented by Figs. 16 and 17.

It is suspended horizontally and provided with gearings, by means of which it can be revolved. One or two manholes are used for filling and emptying. The steam enters through the centre of one or both journals.

Let us first see what we expect this boiler to do, and then how it will have to be constructed to answer the purpose.

I. *Object of Boiling.*—The object of boiling rags is to extract or destroy the fatty, glutinous and coloring substances surrounding the pure fibre, which is needed by the paper-maker.

II. *Chemicals used.*—Alkalies in solution and at a high temperature have been found to accomplish all this, but there are many different opinions as to which and what quantities of them should be used.

Mr. Planche in his work, *De l'Industrie du Papier*, recommends soda alone for the finest, lime alone for the coarsest, and a mixture of both for the intermediate grades of rags.

The author has compared the experience and results obtained in a large number of the best mills in the United States, and has found that nearly all of them use lime alone in the rotaries, and that they obtain as large a proportion of paper from their rags as the manufacturers of any other country, while their producc, especially in the New England States, has no superior in color, purity, and strength.

III. *Theoretical Explanation of the Action of Lime.*—We shall try to give a theoretical explanation of this fact.

Those who advocate the use of soda give as a reason for its preference that water readily dissolves it, while it cannot hold more than $\frac{1}{1200}$th part of its weight of lime in solution.

Contrary to the general rule for other substances, hot water dissolves less lime than cold water.

At	32 degrees Fahr.	water	dissolves		$\frac{1}{600}$	of	lime.
"	60	"	"	"	$\frac{1}{700}$	"	"
"	212	"	"	"	$\frac{1}{1250}$	"	"

A moderately-sized boiler contains over 10,000 pounds of water, and then holds about 8 pounds of lime in solution. But these 8 pounds are immediately absorbed by the fatty and other matters, with which the lime forms insoluble calcareous soaps.

The water then takes up another 8 pounds, again delivers them to the fat, gluten, color, &c., and so on until all the substances which have any affinity for lime have entered the new association.

If too much lime is present the excess will be useless, but also harmless, because so little of it is in solution, and even that is soon transformed into insoluble carbonate of lime when exposed to the air, and as such devoid of all action on fibres.

If an excess of soda has been used, it will remain soluble, and act upon the fibres as long as the rags are not washed perfectly clean.

This theory corresponds with the facts, and also seems to indicate that lime causes less waste than soda. We believe that careful observers will find this to be also borne out by experience.

IV. *Boiling with Soda.*—It has been found, however, that some colors withstand the action of lime, but succumb to soda, and in such cases the latter may be used to advantage.

We know, for instance, a paper-mill, where the colored cuttings of a calico-print mill are made into flat-cap paper.

They are first boiled with about 5 per cent. of lime in a rotary, washed in the engine, and emptied into drainers, then again put into a rotary, and boiled with a solution containing 2 pounds of soda ash for every 100 pounds of rags. The first boiling does not destroy all the colors, especially the red ones; but after the second operation the pulp is as well discolored as that from white rags. A single boiling with mixtures of lime and soda was tried unsuccessfully.

We should advise in all cases the use of plenty of lime alone first; but if it is found that some colors are not destroyed by it, to add 1 to 5 per cent. of soda ash, or, if that also should be insufficient, to boil the rags a second time in a solution of caustic soda.

It will be thus easy for any intelligent paper-maker to establish a rule for the treatment of every kind of rags used by him.

V. *Quantity and Quality of Lime.*—The quantity of lime used varies, according to the nature of the rags, from 5 to 15 pounds per 100 weight. 10 to 15 per cent. are, for example, necessary for gray and blue linen.

The lime should be fresh and in lumps, because its powder is very quickly transformed into carbonate of lime by the action of the air, to which it offers a large surface.

It is the caustic lime alone which is wanted; while the carbonate of lime is equal to and as useless as limestone before it is burnt. Pure limestone (CaO,CO_2) is a combination of oxide of calcium (CaO) with carbonic acid (CO_2). It is the object of the burning operation to drive out the carbonic acid, leaving caustic lime (CaO) in the kiln.

When a long time exposed to the air, as for instance in walls as mortar, it takes carbonic acid from the air and forms again limestone.

VI. *Preparation of a Milk of Lime.*—Square wooden boxes are mostly used for

dissolving lime, and they are often so small, that they will not hold a sufficient quantity of water to make a liquor which can be well strained.

A circular sheet-iron tank of 5 to 6 feet diameter and 3 to 5 feet depth, with an agitator turning in the lower part of the pan by means of gearing, would be an improvement on the wooden box. Fill this tub to $\frac{3}{4}$ with water, and boil it by means of a steam pipe, which enters at the lower part. Then hang into it, on rods laid across the tank, a sheet-iron basket of about 2 feet diameter and 2 feet depth, perforated all over with $\frac{1}{2}$ inch holes, and put the lime into it. The water, entering through the holes, slackens the lime, carrying it off and leaving the stone behind. The slowly turning agitator holds it in suspension until it is drawn off through a valve in the bottom, passed through a strainer of No. 10 to 12 wire cloth, and let into the boiler. A finer screen (No. 40 to 50) may be laid across the manhole to keep out finer particles of sand and grit.

VII. *Filling and Boiling.*—A boiler of 20 feet length and 6 feet diameter holds about 4000 to 5000 pounds of rags, and the larger part of them should be packed in before the lime is added. After it has been filled with rags and enough lime, water must be run into the boiler to fill it above the centre, so that no steam can enter without passing through it. If sufficient water is not used, the rags will come from the boiler dark-looking, as if they were burnt; and no amount of washing or bleaching can make up for the bad boiling caused by a want of water.

After the manholes have been closed, the boiler started, and steam turned on, the pressure must be kept up for ten to fifteen hours, the steam blown off, and the boiler emptied.

VIII. *Blowing-off and Emptying.*—Some boilers have a false, perforated iron head, to allow a stationary pipe, connected with an outside one through the centre of the journal, to reach down nearly to the bottom or shell. Before emptying the rags, the valve of this pipe is opened, and the liquor forced out through it by the steam pressure inside. This is done to facilitate the subsequent process of washing.

The liquid, being driven out with considerable force, undoubtedly carries with it a good many fibres which might otherwise be saved, causing a loss which is more than an offset for any benefit that might be derived from the operation.

It is better to blow off the steam, while the boiler is standing still, from a valve G on top, which is covered inside by a large plate of perforated iron, to prevent the steam from carrying small rags along.

The manholes are then opened, the boiler put in motion, and the contents emptied on a floor slanting to a centre, through which the liquor can drain off.

IX. *Check-valve.*—The rotary is usually in direct communication with the steam-boiler by pipes. The steam must pass through a substantial check-valve before entering the rotary, to prevent its contents from being forced back into the steam-boiler, if the pressure therein should at some moment be less than that in the rotary.

If not regulated in some manner, the pressure in the rotary is usually the same as in the steam-boiler, less a few pounds lost on the way from one to the other. But

if a demand for steam is suddenly made on the steam-boiler from other sources, its pressure goes down, and the steam in the rotary must force the liquor back into the steam-boiler, unless it is cut off by a check-valve.

X. *Explosions.*—A great many rotary boilers have lately exploded, spreading destruction all around them; and theories as strange as manifold have been advanced to explain these disasters. The author does not say that all of them are wrong; but why look for doubtful explanations when, in too many cases, the most elementary rules of mechanics have been sinned against in the construction of these boilers.

It has been pretended that terrific explosions could not arise from gradually increased high pressure alone; that it would only crack, but not burst a boiler. This theory, though unsupported by facts, has been largely accepted as true.

A series of experiments was made in 1871 by the United Railroad Companies of New Jersey, under the superintendence of Mr. F. B. Stevens, on grounds near New York, for the sake of investigating the cause of explosions of steam generators. At one of them, witnessed by Messrs. B. F. Isherwood and Sidney A. Albert, Chief Engineers of the United States Navy, detailed by the Navy Department, and other gentlemen connected with the manufacture and superintendence of steam generators, a boiler was exploded by over-pressure, without any other cause.

An old return tubular steamboat boiler had been selected for the purpose. It was tested several times by hydrostatic pressure, and when tried, on September 2d, 1871, with 60 pounds, twelve of the inside braces gave way. They having been repaired, 30 pounds pressure were put on, and the boiler stood it; on the 16th of November it also sustained 40 pounds steam pressure without injury. The boiler was provided with water-gauges; five carefully tested pressure-gauges near it, under bomb-proof covers, and two pressure-gauges at 450 feet distance, connected with it by a pipe. During the experiment the pressure on the different gauges was compared, and found to agree on all of them.

The water-level in the boiler was 15 inches above the level of the tubes seven minutes before the explosion took place. The gauges indicated a gradual rising of steam pressure until it reached 50 pounds to the square inch, when some of the braces gave way with a loud report, and at a pressure of $53\frac{1}{2}$ pounds the boiler exploded with terrific violence. The steam-drum and a portion of the top of the shell, forming a mass of about 4 tons in weight, were hurled high into the air, and fell about 500 feet from the inclosure. The boiler was literally torn into shreds, and only a mass of shattered tubes remained on the spot where it had been. The ground, for a considerable space around, was saturated with the water it had contained. This boiler had a certificate for 30 pounds pressure. At the experiment, wood alone was used as fuel, and in only thirteen minutes the pressure rose from the allowed 30 pounds to $53\frac{1}{2}$, at which the boiler exploded.

In many paper-mills the back tender is at the same time fireman, and is often absent from the powder magazine, called a steam-boiler, for more than fifteen minutes at a time. It is a wonder that explosions do not more frequently occur.

Rag-boilers directly connected with, and therefore liable to the same pressure as the steam generator, should be built on the same principles. If they are not, an occasional neglect of the fireman, by running the steam up too high, may burst the rotary, while the generator remains unaffected.

The larger the diameter of a steam-boiler the stronger is the tension on any part of the shell. A wrought-iron pipe of 2 inches diameter will stand a very heavy pressure with only $\frac{1}{8}$ inch iron; while nobody would think of constructing a steam-boiler of 3 feet diameter, for 70 pounds pressure, of less than $\frac{5}{16}$ inch sheets.

The tension of the iron, or the power which tries to tear it asunder, increases in direct proportion to the diameter and pressure; its thickness or strength of resistance must therefore increase likewise.

This rule, which is generally accepted and followed for the construction of steam-boilers, should be in operation for our 6 and 7 feet rotaries.

F. Redtenbacher gives the following rule for the thickness of the sheet iron used for cylindric steam-boilers:

$$d = \frac{1.315 + 0.495}{363 - n} D$$

In this formula D represents the inside diameter of the cylinder in centimetres (1 inch is equal to a little over $2\frac{1}{2}$ centimetres); d the thickness of the sheet iron used for the cylinder; n the number of atmospheres, representing the highest pressure of steam allowed in the boiler. The pressure of the atmosphere changes, as indicated by the barometer, but may be taken at 15 pounds on the square inch. It must also be remembered that the steam pressure gauges in the United States only show the number of pounds above the atmosphere; and in order to get the real pressure n, one atmosphere must be added to the indicated pressure.

This formula has been calculated for different pressures, and gives for 1 to 8 atmospheres:

$n =$	1	2	3	4	5	6	7	8
$\frac{d}{D} =$	0.0050	0.0064	0.0077	0.0092	0.0106	0.0120	0.0139	0.0149

Supposing, for instance, that the highest pressure carried by the steam-boiler is 75 pounds on our gauge, and that a rotary of 6 feet diameter is in uninterrupted communication with it, the real pressure n is $75 + 15 = 90$ pounds, equal to 6 times 15 or 6 atmospheres. D the diameter is 6 feet or $6 \times 12 \times 2\frac{1}{2} = 180$ centimetres. We find for $n = 6$:

$$\frac{d}{D} = 0.0120 \text{ or } d = 0.0120 \times D = 0.0120 \times 180 = 2.16 \text{ centimetres} = \tfrac{7}{8} \text{ inches.}$$

If a steam generator of 6 feet diameter for 75 pounds steam pressure should be built, no mechanic would dispute the propriety of using 7 inch iron; but for a rotary in the same conditions, $\frac{5}{16}$ inch, and even $\frac{1}{4}$ inch, is often considered sufficient.

It must be admitted that the above-stated formula gives very safe boilers, but that is what is wanted.

It is also true that the steam-boiler, being exposed to the wear and tear by fire, needs heavier iron on that account than a rotary.

It is not intended to recommend the use of iron according to the above-stated rules; but they may serve as a guide, and show that it will not do to build rotaries of different diameters with sheets of iron of the same thickness. It must also be considered that the shell of a rag-boiler, being by turns wet, dry, hot, and cold, is very liable to be weakened by rust and expansion and contraction.

The shell of a 6 feet rotary, carrying 75 pounds of pressure, should be made of best $\frac{1}{2}$ inch iron, double riveted, and $\frac{1}{16}$ inch should be added to the thickness for every foot increase of the diameter.

We admit that a shell of $\frac{3}{8}$ inch iron, as recommended by many machinists, is sufficient so long as it retains its full strength. But if, in the course of time, the boiler is weakened by wear and tear, and the same high pressure is used, an explosion will be natural.

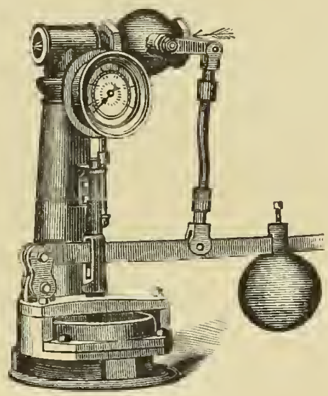
The rotaries should therefore be constructed stronger, or not exposed to as high a pressure as they are in most mills.

According to the opinion of many experienced paper-makers, it is better to boil rags slowly, at a moderate temperature, than to force the operation with high pressure.

A pressure of 30 pounds would be sufficient for any kind of rags; and if we can only succeed in keeping the steam in the rotary down to that point, the danger of explosion will be reduced so as hardly to deserve any consideration.

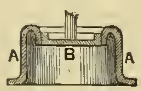
In some New England mills an apparatus is used for this purpose which seems to answer all reasonable expectations. It is manufactured by the Union Water Meter Company, Worcester, Mass., as represented by Fig. 14. A branch of the steam-pipe supplying the rotary leads to a large valve carrying lever and weight, like a safety-valve. This lever is connected by a rod with the shaft of a throttle-valve, admitting or closing off the steam. If the weight is set so that the safety-valve is raised up at 30 pounds pressure, the lever will go up likewise and, through the connecting rod, close the steam-valve. If the pressure falls below 30 pounds, the steam-valve opens again, and thus keeps it at the desired point.

Fig. 14.



The valve is not constructed in the ordinary manner. A rubber cylinder or a section of rubber hose A A, as shown by a cut in Fig. 15, is fastened with its lower edge to the iron frame, and the upper edge carrying the valve B is bent in so that the valve may move freely up or down. The hollow column, through which the steam descends into the chamber formed by the rubber cylinder and the valve, is and should always be filled with condensed steam or water,

Fig. 15.



to prevent the steam from coming in contact with the rubber. A gauge attached to the column shows the pressure.

XI. *Construction.*—The rotary derives its name from being suspended on its ends in journals, wherein it revolves. These journals form part of the heavy castings,—the ends of boiler-heads riveted to a cylindric shell, and are of about 12 inches diameter and 12 inches length in their bearings.

Some boilers are built with wrought-iron heads, and journals with cast-iron flanges of about 3 feet diameter are riveted to them. The whole weight of boiler and contents, amounting to 10 and often 20 or more tons, is sustained by these flanges and rivets. The rivet-holes necessarily weaken the castings; and the author has seen the flanges of such boilers broken right through them in a circle, showing that the weight and wear and tear of the motion was more than they could stand.

A rag-boiler, which was ordered by the author, and built by Pusey, Jones & Co., Wilmington, Del., is represented by a vertical section through A–A of Fig. 17, in Fig. 16, and by an elevation showing the driving end in Fig. 17, at about $\frac{1}{64}$ of the

Fig. 16.

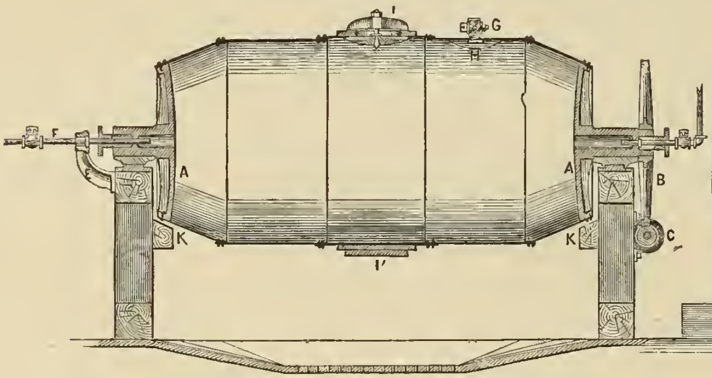
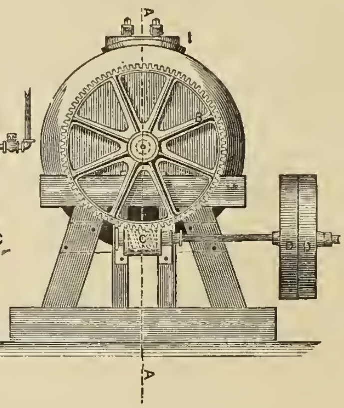


Fig. 17.



real size, or $\frac{3}{16}$ inch per foot. By forming the heads A A in the manner shown in Fig. 16, of one solid casting, arched and smooth inside, and strengthened by ribs outside, the weight is divided on a large circumference and many rivets.

A 6 feet shell should be riveted on heads of not less than 5 feet diameter, like A A; but if false heads and syphon pipes are used inside, the shell must be cylindrical to the ends.

Castings, even if made with the greatest care and of the best iron, are liable to be faulty, although the defects may be invisible.

Every rotary should be tested with the same hydrostatic pressure as the steam-boiler with which it is to be connected. We have seen several apparently sound heads cracked when subjected to it.

One of the journals has an additional length of about 6 inches, carrying the cog-wheel B which turns the boiler.

The journals of most rotaries are each one separately turned, and afterwards riveted to the shell. It is impossible to fasten them so that they will be perfectly in line; boxes turning on pivots, which accommodate themselves to the journals, are therefore generally used. The fault is not hereby corrected, but only hidden, and the friction, wear and tear, and probability of breaks are greater than if the journals were in line.

The only way to make a rotary run true is to rivet the heads in rough, to put the whole boiler into a large lathe by means of a crane, and to turn the journals there. If the necessary machinery is provided, this is fully as cheap as the old way. The boiler represented by Figs. 16 and 17 was thus bodily turned.

The movement of the rotary causes the rags to rub against one another and against the boiler, creating a loss and weakening the fibres.

A very slow motion, sufficient to mix the rags with the liquor, and reducing the loss by friction to a minimum is therefore desirable. One revolution in five to ten minutes is sufficient.

In most cases many cog-wheels would be required to reduce the speed so low, but it can be easily and satisfactorily done by a worm-wheel. Such a wheel B, of about the same diameter as the shell, with tight and loose pulleys D D on the worm-shaft, answers well, and gives the additional advantage that the boiler stops easily in any position, held by the worm C, as soon as the belt is shifted on the loose pulley.

The steam-pipes, as far as they pass through the journals, should consist of castings turned in a lathe, and fastened in some way to the boiler-frame, so that they cannot be carried round by the friction. A square nut, which is cast with the pipe F, is thus held in its place by the bracket E, which also supports it against the pressure inside of the boiler.

Stuffing-boxes prevent the escape of steam or liquor between the journals and pipes.

To blow off steam the rotary must be stopped, and a pipe leading out of the building attached to the stop-valve G, the inlet to which is guarded by the perforated sheet-iron H.

A portion of the heat which thus escapes can be saved by conducting the steam through pipes surrounded by cold water, which is thereby heated, and may be used for many purposes.

The iron sheets should overlap each other like shingles on a roof, descending towards the manholes, so that the rags cannot find any corners wherein to lodge while the boiler is emptied.

The manholes I are ellipse-shaped, of wrought-iron, not too heavy, and fit against the shell from the inside, so that the increasing steam-pressure will close them tighter all the time.

Many materials are used for packing them, but the most convenient are braided hemp rings saturated with clay, as ropes and clay are always on hand in paper-mills.

The boiler must be well balanced to run easy, a sham manhead or casting I′,

equal to the overweight of the real one, is therefore frequently fastened opposite. If turned in the lathe the rotary can be balanced better than in any other way.

XII. *Location of the Rotary and Disposition of the Boiled Rags.*—In a well-arranged mill the rag-boiler, as has been said before, is always situated so that the top nearly reaches the floor of the duster or rag-room, and high enough to allow it to empty easily on the drainer-bottom below. The rags are from there loaded into trucks and hoisted up to the engine-room. If the boiler-room floor can be put on a level with that of the engine all the hoisting is saved. To accomplish this a high foundation is often required. Good-sized timber, of not less than 10 by 12 or 12 by 12 inches may be used for it, but in some cases stone or iron will be found cheaper, or preferred because they are fire-proof.

To provide against accidents, such as the breaking of a journal, it is prudent to let an offset of the foundation or pieces of timber K K extend under and close to each end of the boiler, so that it cannot fall to the ground.

The rags must be drained while hot, because some of the substances dissolved in hot water are insoluble in cold water, and would, if suddenly cooled off, deposit again on the rags. The more perfectly the liquor is drained off before the rags are taken to the washing-engine, the better. If not too expensive it would be advisable to wash them in hot water.

There is no better evidence of the perfection with which this process of boiling extracts the glutinous and other substances from the rags than the fact that Messrs. Delaire and Bocquet in France have lately succeeded in sizing paper, with an extract made from the liquor which escapes from the rag-boiler. The process is patented.

Rag-boilers should be situated in buildings or rooms strictly separated from the other parts of the mill where labor has to be performed, because the rags are, and ought to be, boiling hot when emptied, and the steam coming from them fills every department within its reach. Especially in cold weather this is very disagreeable, and injurious to the health of the employees.

12. Tubs preferred to Rotaries.—Several manufacturers of fine writing-paper have lately discontinued the use of rotaries, and do their boiling now in wooden tubs with a very weak solution of caustic soda. They use none but the best qualities of white rags, and think that they not only suffer a greater loss of fibres from rotation, but also that scales and rust from the iron of the boilers find their way into the pulp.

The weaker treatment in tubs is quite sufficient for such material, and the change may be a very judicious one.

SECTION III.

(*a*) Washing, (*b*) Bleaching, (*c*) Draining, (*d*) Bleaching with Gas.

(a) *Washing.*

13. **The Engine.**—The invention of the engine or Hollander has laid the foundation for the present development of the manufacture of paper, and though over one hundred years have passed away since its introduction, it is yet very imperfectly understood and constructed.

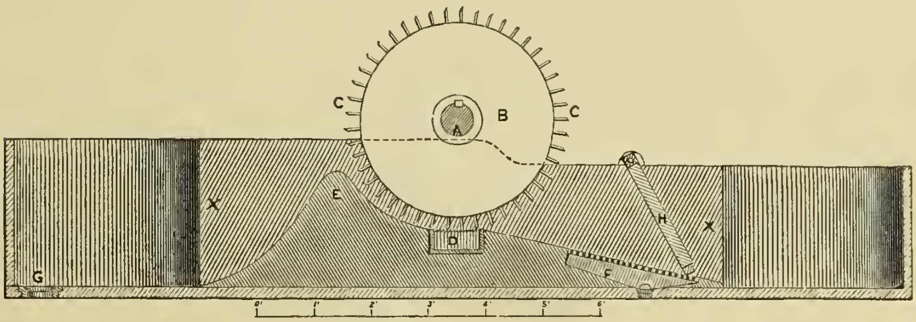
The rags are washed and beaten into pulp for the lower grades, such as wrapping paper, in one engine, but this section treats only of the operations by which "half stuff" is made.

If half stuff or bleached pulp is to be made, the washing and beating have to be done in different engines, and each one can be constructed so as to perform best the work for which it is intended.

In the discussion of the engine in this section, its character as a washer must be kept in view.

This well-known apparatus, a theoretical section of which is shown in Fig. 18, may be defined as a shallow, oblong vessel, with circular ends divided lengthway by

Fig. 18.



a partition X, which extends as far as the rectangular part of the body. A shaft A, bearing a roll B, which fits into one of the two partitions, revolves across the middle of this vat. A number of steel knives C are fastened parallel with the shaft on the surface of this roll, and another set D is placed right under it on the bottom of the tub, so that the edges of both face and touch each other.

Between these two sets of knives, the first one C revolving, and the latter one D stationary, the rags must pass, and are cut, torn, or only rubbed, as may be desired.

A stream of pure water flows into the engine, is thoroughly mixed with the pulp through the action of the roll, and the dirty water is constantly washed out by a

mechanical contrivance, which will be described hereafter. The distance between the knives can be regulated by lifting or lowering the roll-shaft A with the lighter.

14. Furnishing and Washing.—The engineer in charge opens the water-faucet, and, as soon as the vat is partly filled, throws the boiled rags into it, behind the roll, so that the revolving knives C can take hold of them. The assistant or helper must have a full supply of rags ready on trucks, as no mill can afford to waste the time of the washers or beaters.

To get the full strength of the raw material, it is necessary to preserve the length of the fibres. If chopped into short pieces a part of them must invariably be lost with the wash-water. The roll should therefore never be lowered any further during the wash-process than is necessary to turn and draw out the rags.

In furnishing the engine it is often found that some rags sink to the bottom, while others float on top. The first are evidently heavier and the latter lighter than water. Though both may be composed of the same kind of fibre, it is in one case woven into a compact mass of a greater specific weight than water, and in the other one it is spread out so that a pound of it occupies more room than a pound of water.

Heavy rags must be made to occupy more room by being drawn out and torn into shreds; light ones must be bruised, soaked in water, and pressed together to gain in weight.

These two different results are, strange to say, obtained by the same action, and just the one which, according to our previous explanation, is to be strictly avoided.

The engineer lowers the roll so that it nearly touches the plate, and then pushes the heavy or light rags under it with the paddle. A few turns round the engine are usually sufficient to crush the rags into obedience, so that they will neither rise to the surface nor sink to the bottom. The roll, of course, must be raised again immediately, and kept so until the wash-process is finished.

This is not the case until the water runs perfectly clean from the washers. Then, and not before, it is time to lower the roll, so that the rags may be drawn out into their fibres, but not cut.

It is our aim here, and all through the process of paper-making, to obtain the original fibre as little damaged as possible; the washing engine, which plays an important part, should therefore not be trusted to any but men of judgment and experience. The damages and losses suffered here cannot be repaired or recovered.

The efficiency of the engine depends in a great measure on the velocity with which its contents circulate. If the rags pass twice between the knives of one engine, while they go only once through those of another, the former does nearly twice as much work as the latter in the same time.

The rags cannot be well washed unless the fresh water, which is constantly pouring in, becomes speedily and thoroughly mixed with the pulp.

15. Movement of the Pulp.—This mixture will be the more perfect, the oftener the pulp is subjected to the action of the roll within a given time.

If the whole mass moves lazily, the heavy portions settle to the bottom, and lodge

in corners, but a lively current gives them an impetus, which overcomes their weight and carries them along.

Nearly every millwright and machinist has a plan and theory of his own, by which this object is to be accomplished.

Many years ago the midfellow was frequently placed out of centre, on the theory that the pulp would stand higher in the narrower part, and thereby produce a current down to the pulp in the wider partition.

The present construction of our engines disproves this, and it is only mentioned because it was taught by a justly celebrated authority in mechanical engineering.

The movement of any mass consumes power, and the only power in an engine is exercised through the roll, which consequently must be the cause of circulation.

The action of the roll, by taking hold of the rags, dragging them up to the backfall E, whence they tumble down again, starts the movement. But, by and by, the rags are macerated into thin pulp, in which there is not solid substance enough to be pulled by the knives, and then the roll acts as a pump or water-lifter.

The machines used by the Egyptians, thousands of years ago, to raise water for irrigation, have very much the appearance of low-breast water-wheels, or would on a small scale resemble the rolls of our engines. Their action is that of a water-wheel consuming instead of producing power, creating a waterfall instead of using it.

The circulation is proportionate to the quantity of pulp, which is transferred or raised by the roll from the lower to the upper part of the saddle-shaped breast or backfall E in a given time.

The quantity of pulp which can be forwarded depends, first of all, on the size of the buckets formed by the flybars C. These latter should be of strong $\frac{1}{2}$ to $\frac{5}{8}$ inch iron plate, edged with steel as far as they are to be worn down; they should stand alone, and project as far as possible from the body of the roll.

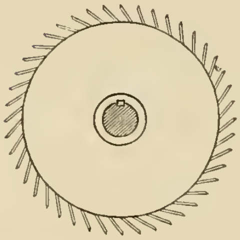
By crowding too many flybars on the roll, the space between them, and with it the lifting capacity, is decreased, and what might be gained by the increased number of cuts is lost in circulation. The distance between their outside edges should not be less than $2\frac{1}{2}$ inches—better more. The distance between the flybars being fixed, the diameter of the roll B determines their number.

To prevent the buckets from losing their contents before they have reached the point of discharge, the backfall, like the drain of a water-wheel, must be shaped so that the edges of the flybars or buckets pass it close enough not to leave room for the escape of pulp. Sometimes this is done so well that the pulp cannot even leave the flybars where it ought to, and is carried round by them. This will be found on examination to be the case with many poorly-turning engines.

It is evident that the pulp which has not been discharged before the flybars reach the horizontal position (usually at the height of the centre of the roll) must be carried farther, and return to the point whence it started from. The usual way to avoid this is by leaving a wide space of 2 to 3 inches between the flybars and the backfall at the upper end for the reception of the pulp. We have also seen the

flybars put into the roll, so that they do not point towards the centre, and consequently reach the horizontal position only several inches above the centre line, as represented in Fig. 19. The flybars in this drawing are put more out of centre than is practically done, in order to show the principle. The edges may, however, in all cases be moved backwards from the central position about $\frac{1}{4}$ to $\frac{1}{2}$ inch.

FIG. 19.



16. Rolls.—The top of the backfall is, if built correctly, kept considerably below the centre line. But why do we not see any engines with large rolls,—so large that the whole shaft is above the engine sides, and its centre necessarily far above the backfall?

There cannot be any serious objection while everything speaks in their favor. Such large rolls will carry more knives, forming large buckets; they can with less revolutions make as many cuts; they are heavy and therefore preferable; and last, but not least, the sides of the engines need not be cut, and as the shaft rests above the level of the pulp, none of it can escape through the holes.

If the common small-sized rolls are chosen, the backfall is to be fitted close at the bottom near the plate, widening out to the top. It must be kept low enough to remain several inches beneath the centre of the roll.

A well-built engine does not require more than $\frac{1}{2}$ to $\frac{3}{4}$ inch play between the roll and the engine sides, and even that space soon fills up with rags, if not kept clean by a narrow strip of wood or metal fastened to the heads of the roll.

It is very important that the rags should not find any place where they can lodge, escape the washing and beating process, and become mixed with the prepared pulp while emptying. The little strips just spoken of, trifling as they seem, should not be neglected, as they will, if judiciously put on, keep the sides of the roll clean.

No roll, if ever so heavy, can descend any lower than the lighter which carries it will permit, but nothing besides its own weight prevents it from jumping up. If a light roll is called on to forward or grind a thick bundle of rags which it cannot master, it will either refuse to work or jump out of its place, and perhaps break something, while a heavy one would give no difficulty whatever. Large, heavy rolls are therefore preferable to light ones.

There is no good reason why iron should not in engine-rolls, as well as in other machinery, take the place of wood. The difficulty of finding trees large enough to furnish them enforces the substitution of iron, which is besides less perishable and heavier.

17. Shaft.—The shaft must be strong and stiff, so that it can neither break, spring, nor bend; and it is simply a question of cost if wrought or cast iron is to be chosen, provided that these conditions are complied with. The shafts of our 600 to 800 pound engines are usually of cast iron, 6 to 7 inches diameter, and often preferred to wrought-iron ones, because they are more rigidly stiff and much cheaper. The latter have, however, a tenacity, nearly excluding the possibility of breaking, which castings, if ever so well made, always admit of.

18. Backfall and Tub.—The backfall is mostly made of wood, and soon worn out of shape if not covered with cast-iron plates or heavy sheet copper.

The vat is constructed either of wood, iron, or stone. If of wood, it should be of a tough-grained kind, which will resist the influence of water and chemicals for a long time. 3 or 4 inch plank, standing upright, the circular parts surrounded by iron hoops, compose the sides; the bottom is 3 to 4 inches and the midfellow 2 to 3 inches thick. The fine paper of the New England States is nearly all made in wooden engines, with or without copper covering. Cast iron is more substantial than wood, and cheaper than wood covered with copper, and should be used at least for the sides of engines, excepting only those in which the finest grades of paper are made, which may be damaged by traces of rust.

Many engines are now built entirely of iron; and those of one of the largest new mills in the United States, carrying 600 to 800 pounds, consist of one solid casting, including sides, bottom, and backfall.

If, however, any change in location should necessitate a change in the engines—for instance, only a new outlet valve—it could not be made without difficulty.

Whatever material may be used, the engine must be built so as to leave no holes or corners for the pulp to lodge in. The corners formed by the bottom and sides must be filled or rounded up.

Stone tubs can only be procured of small size, and are used exclusively for bleaching. The nature and size of the stone governs their construction.

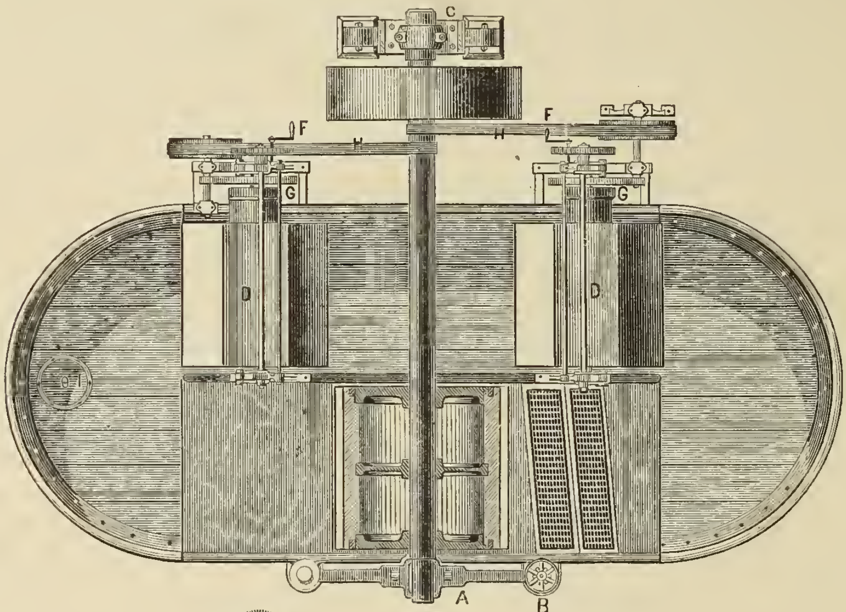
19. Sand Traps.—Every engine should be provided with sand traps F, or excavations in the bottom, covered with perforated cast-iron or brass plates, wherein heavy impurities, like nails, buttons, stones, metals of all kinds, and sand deposit themselves. The openings in the plates may be as numerous and as large as the strength of the metal will admit of; the pulp will go through anyhow, and can only be displaced by heavier matters. If the openings are too small, they will keep the larger pieces of metal out. The efficiency of the sand traps is proportionate to their surface. They must be located so that the water, with which the pulp is washed down when an engine is emptying, cannot reach them, stir up the impurities inside, and carry part of them off with the pulp. This would be the case everywhere near the discharge-valve, or between it and the point where the fresh water comes in. The only safe place seems to be the ascent to the roll, and on it we find it usually located.

The lowest point of the cavity F, covered by the sand trap, is usually provided with a valve, through which it can be cleaned out. Sometimes, however, this valve is placed, for greater convenience, in an upright pipe alongside of the engine, and connected by another pipe with the lowest point of F. It can then be opened and the contents of F at any time drawn off, by means of a rod and handle, while the engine is running. But, as this valve cannot be seen, there is danger that, with the impurities, some pulp may escape, through carelessness in opening it too often and not closing it perfectly after use. It is, therefore, questionable if the greater convenience is not offset by the danger of loss.

A washing engine, which is a fair example of those most seen in the paper-mills of this country, is shown by a plan and front view, drawn to a scale of $\frac{1}{4}$ inch per foot, in Figs. 20 and 21. It has iron sides, iron roll, wooden bottom, and carries about 500 pounds.

20. Lighters.—The roll shaft rests in two bearings, outside of the tub; one of them next to the roll, or, as it is called, "on the front side," is carried by the lighter A.

Fig. 20.



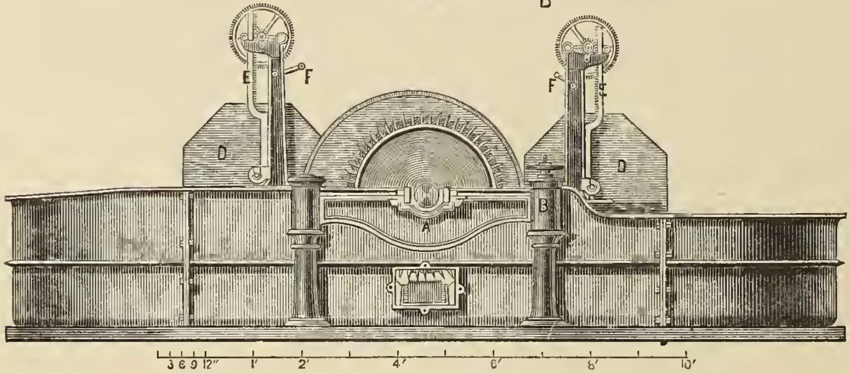


Fig. 21.

This lighter (a horizontal lever) is fastened by a pin at one end, and can be raised or lowered by means of an upright screw and hand-wheel B at the other end, the bearing and shaft following these motions. The back end of the shaft rests on a separate stand C, at some distance, leaving room for pulleys between it and the back side.

Whenever the shaft is raised or lowered by the lighter, it occupies a more or less inclined position, or, to speak correctly, makes a different angle with the horizontal

line. If the two bearings or shells do not follow these motions, the shaft will only lay in them in one position, while in all others it will rest on a corner of the box only. Instead of being immovable, the bearings should turn on pivots, which permit of their changing positions with the journals.

It is evident that the rags can only be treated alike by the roll, so long as the distance between the revolving and stationary knives is everywhere the same. When the lighter is raised or lowered, it is done with the intention of increasing or reducing that distance to a certain opening; but how can this be done if the two sets of knives are not parallel?

The bed-plates are so set that they are touched all across by the fly-bars, when in contact with them; but this position is seldom allowed while working. The lighter is always more or less raised, the shaft and fly-bars forming an angle with the bed-knives. If the length of the roll is about one-third of that of the shaft between the two bearings, and the front corners of the fly-bars are raised to about $\frac{3}{8}$ inch above the plates, the back corners can only be $\frac{2}{8}$ or $\frac{1}{4}$ inch off; or there is always one-third difference between the openings at the two ends.

An engineer would laugh if he were told that it did not make any difference if the fly-bars were raised $\frac{1}{4}$ or $\frac{3}{8}$ inch; and yet we allow the same pulp to be subjected to such different treatment at all times in our engines.

As the plates are wearing down, the roll follows them, and, its shaft being stationary at the back end, it will descend lower at the front side than near the mid-fellow. Every paper-maker knows that the plates, on being removed, are always worn most near the outside of the tub. If they are, for example, reduced $\frac{3}{8}$ inch at the front side, they will only be $\frac{1}{4}$ inch below their original height at the back end.

As the plates can be worn down by the friction of the rags only, we are forced to the conclusion that the rags have been subjected to the strongest action where most of the steel has disappeared, that is, on the front side.

The fibres will be more of one length if treated uniformly; and the more they are so, the fewer of them will be wasted.

The shaft and tub must preserve their original correct position towards each other, by being fastened immutably to one and the same foundation. The most perfect way to assure this is by attaching the back side bearing to the tub itself. If it rests on a separate stand, the relative positions between it and the engine may be changed by a difference in the settlement of the foundation, or by a lateral displacement of either. But, if an immovable bearing is attached to the engine, the shaft will be much shorter, and the angle formed by the fly-bars and plates considerably increased.

We have to choose between the two evils, of a separate stand, with the danger of relative dislocation, and an attached bearing with short shaft, unless a plan is adopted by which both can be avoided.

It can be done by resting the shaft on two lighters, both moving up and down together. The front side lighter is, as usual, lowered and raised by a screw, which

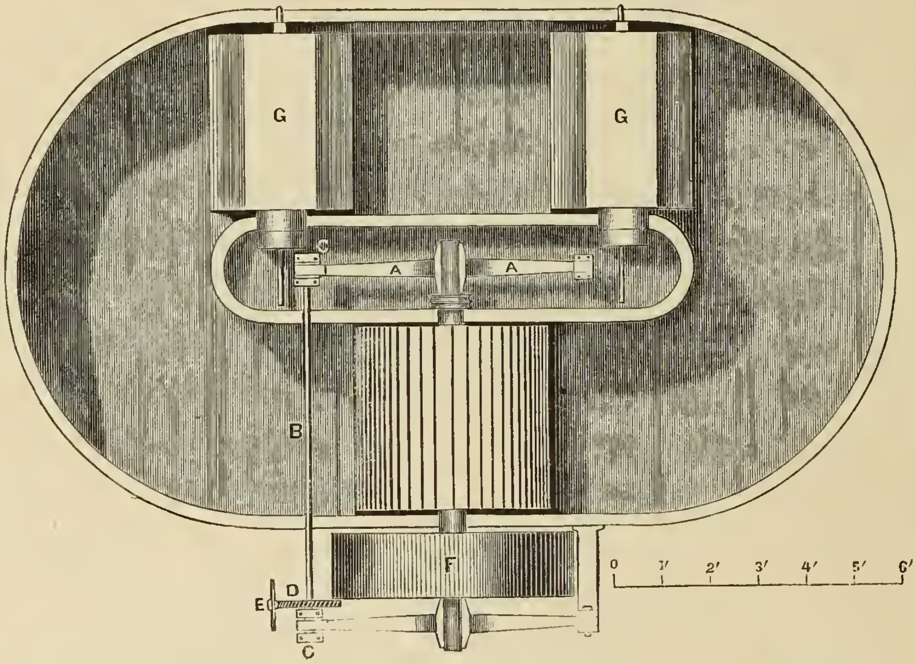
connects, by bevel-wheels and a horizontal shaft across the engine (either above or below), with the screw of the back side lighter.

If the connecting-shaft is above the engine, it must be carried on high stands, so as to be out of the way; but if it is located below, it may lay close to the bottom, not obstructing anything. The latter plan is the simplest and cheapest.

It is true that these connections would have to be strong and heavy for our large engines, and would cause additional outlay; but the larger the engine is, the more unevenly, with the present construction, will it cut.

The bed-plate will wear down with more uniformity than in ordinary engines if the roll-shaft is periodically lowered at the back end, and thus, in a manner, reset. This can be done with a set-screw under the bearing of the shaft, on the back side

Fig. 22.



stand. It can be found by experience how much the plates wear down in a given time, and then the back side bearing is, at fixed times, lowered as much.

In a mill where all the engine-shafts are supplied with such movable bearings, it has been found that $\frac{1}{16}$ inch is worked off from the height of the bed-plates every two weeks. The foreman therefore lowers the set-screws every two weeks, and with them the bearings, by one turn or $\frac{1}{16}$ inch, and permits of the rolls touching the plates and grinding all along their surfaces, as they did when the plates were new.

This is an improvement on the immovable bearing, but requires attention, and corrects the faults only periodically; while an arrangement by which both ends of the shaft are raised and lowered together, keeps it all the time in correct position.

We have seen at Messrs. Cheney & Hudson's bank-note paper-mill, near North

Manchester, Connecticut, a washing engine for a thousand pounds of pulp, the construction of which deserves to be more widely known. A horizontal plan of it is represented by Fig. 22, on opposite page.

The centre of the engine is a hollow place inclosed by two midfellows, about 18 to 20 inches apart, with ends connected by circles.

Instead of the usual stand on the back side, this engine has a lighter A in the hollow centre, which is identical with the one on the front side. A shaft B across the front half of the engine, resting on stand C, lifts both lighters at once by means of eccentrics. The eccentric shaft itself is turned by a worm-wheel D, and the worm-shaft by a crank or hand-wheel E.

The pulley F is placed between the front side lighter and the engine. The two washers G empty into the hollow centre, and are driven there.

The shaft of this engine, if high or low, always remains in a horizontal position, and the reduction to one-half of its usual length simplifies the construction very much. The outside of the engine is nowhere obstructed by gearing except by the pulley F on the front side; it is therefore more accessible and occupies less room.

H. D. Burghardt, millwright, of Pittsfield, Mass., planned and built the engine, and Mr. Hudson expresses himself, after several years of experience, highly pleased with it.

21. Manner of Driving and Speed.—The large cog-wheels which formerly used to drive the engines have been almost altogether superseded by pulleys and belts.

Belts are preferable, because:

The engines can be set up at almost any reasonable distance from the line shaft;

Belts slip or jump off if a thick solid substance happens to get under the roll, while cog-wheels would break;

The engines may almost always be located above the driving-shaft, and the pressure with which the roll bears on the rags is then increased by the tension of the belt.

The friction by which the pulley is turned is proportionate to the surface covered by the belt.

If once overstrained, a belt will soon be weakened and worthless; strong wide belts are therefore the cheapest in the long run.

The driving belt of a 300 to 400 pound engine should not be less than 10 to 12 inches wide, and 16 to 18 inches width is required for an engine which carries 800 to 1000 pounds.

Rubber belts will withstand the influence of water and of a moist atmosphere, both of which abound in the engine-room, better than leather, and are therefore generally preferred.

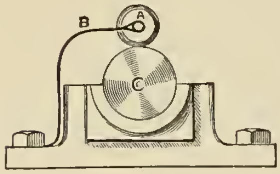
The number of turns per minute which washer-rolls should make has been fixed by experience at from 100 to 150 for rolls of 42 to 36 inches diameter.

22. Bearings.—The bearings may be of any kind of metal, or even hard wood,

and open on top. They should be oiled by some good feeder or with pieces of fat salt pork; the indiscriminate pouring on of oil is not only expensive, but very inefficient besides.

We have seen an oil feeder, which may be made at any mill with little or no expense. It consists, as shown in Fig. 23, of a wooden roll A, of about 2 to 3 inches diameter, and nearly the length of the journal, and is covered with felting, several thicknesses of which have been wound up on it. The journals of this roll are carried by a forked piece of sheet iron B, which is fastened to the box. The felt-covered roll rests on and is turned by the journal C. The oil is poured on the felt, and from it gradually distributed on the journal C.

Fig. 23.



23. **Bed-plates.**—The quantity and quality of the work done by an engine depend to a large extent on the bed-plate.

Though this chapter treats of washing engines and not of beaters, their requirements are in so many respects alike that much of the following discussion holds good for both.

The washers always do the hardest and, where they finish the pulp at one operation, as in wrapping mills, all the work; and must therefore be supplied with substantial bed-plates. The simplest and oldest kind is composed of steeled knives like the fly-bars, bolted together, and placed in a wooden block or cast-iron box under the roll, whence they can be removed at will through an opening in the side, as seen in Fig. 21.

They are always put in oblique, in order to act as shears with the fly-bars, that is, they deviate from the square line about 1 to 2 inches.

The rags are pushed to the side occupied by the forward part of this plate, and it has been improved upon by bending the knives in the middle, so that both ends are equally the backward and the middle the forward points. From its form the latter is called the "elbow-plate."

As said before, the rags are constantly pushed to the forward point, and, as this is the centre, they will stand higher there than at the sides. It can actually be seen in any beater, provided with elbow-plates, where the surface of the pulp is close to the lower side of the shaft. The straight line of the latter shows plainly the curve of the surface of the pulp to be higher in the middle.

The solid elbow-plate is very generally used in washing engines.

Whenever the edges of the plate are worn down, it must be taken out and sharpened, and to avoid this, various new inventions have been devised.

Thin steel plates are cut into the size of bed-knives, and wood or soft metal is filled in between them to keep the edges at about the distance of ordinary plates. The rags wear down the wood much quicker than the steel; the latter projects therefore and constantly presents sharp edges.

This is certainly a valuable improvement, as the plates are kept without assist-

ance at the same degree of sharpness, while solid steel or iron ones are constantly changing from the time they are put in until taken out.

The steel can be bent into almost any desirable shape, of which the most prominent are the elbow and zigzag plates.

Plates of the elbow form, made of thin $\frac{1}{16}$ to $\frac{1}{8}$ inch steel, have the same advantages as the solid ones, and are used by many experienced paper-makers. The majority of the Massachusetts mills use solid elbow-plates in the washers, because they will stand hard knocks better than those of thin steel, but they prefer the elbows of the latter kind for the beaters.

To form the zigzag plate the steel is bent into an undulating line, which appears composed of a large number (fifteen to twenty) of elbows or triangles. They do not push the rags to the middle like the elbow-plate, but as an undulating line is longer than a straight one, they give more cutting surface. Their sharper angles also increase the cutting power, and it is generally admitted that they grind rags quicker than any other kind.

It has been found that the fly-bars are worn out unevenly by these zigzag plates. They are cut by the corners of the triangles or short elbows, so that after some time they acquire more the appearance of saws, and must be frequently sharpened.

There is a larger surface of steel concentrated in the corners than on the same space between them, and the larger friction surface necessarily grinds out more than the smaller one.

Fig. 24.

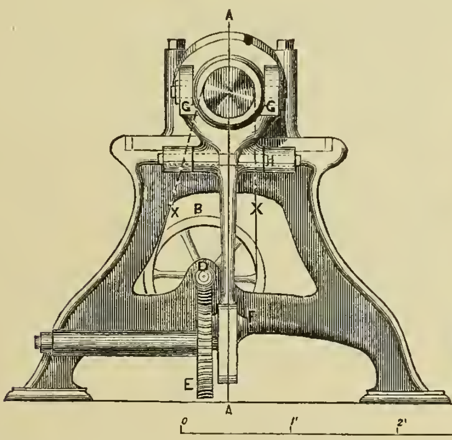
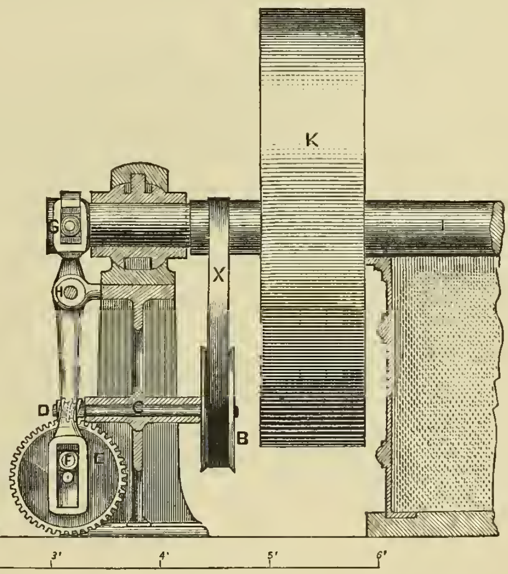


Fig. 25.



Thomas Lindsay has constructed a little apparatus moved by the engine-shaft, which gives to the roll and shaft a slow rocking or lateral motion, whereby every part of the fly-bars is brought in contact as well with the corners as with the rest of the zigzag plate. It is shown by Fig. 24 and Fig. 25, in side view and in section through

A A. The belt X, driven by the roll-shaft, turns the pulley B and the worm D on the same shaft C. The worm-wheel E, driven by D, carries an eccentric F, which moves the forked lever G to and fro. This lever G is fastened at H, and holds and moves the roll-shaft with its forks, giving it a rocking motion of altogether about $\frac{3}{4}$ inch or about $\frac{3}{8}$ inch to each side.

The fly-bars are hereby preserved as uniformly as if any other kind of plate were used.

The six large beaters at Messrs. Jessup & Moore's paper-mill, Rockland, near Wilmington, Delaware, which furnish the pulp for three machines, or nine tons of paper per day, are supplied with these rockers.

Mr. Lindsay has also used a new kind of fly-bars in these engines. They consist of common iron plates, with thin steel plates bolted to them, which, like the bed-plates, require no sharpening. When worn down, the bolts are simply loosened, the steel moved further out, and fastened again.

The large number of bolts, with which the steel is fastened, occupy much of the room between the fly-bars, and are open to objections. If one of them should drop out, it might ruin both the roll and plate. We understand, however, that new engines, which are to be built for the same firm, will be supplied with these fly-bars.

Zigzag plates are often supplied with straight bars at the outside and centre, or the second half of knives is reversed, for the purpose of distributing the corners better, and to prevent them from cutting the fly-bars. Paper-makers who have tried them, have found that these bed-plates injure the roll less, but lose some of their cutting capacity.

It is evident that zigzag plates should be used only for the strongest stock, such as manilla, &c., and only in the interest of quick work. Where quality is more an object than quantity, no sharp knives of any kind are to be allowed in the engine.

Cast-iron blocks, the tops of which are planed or cut into sharp ridges, are successfully used for very coarse papers.

Lately even stone bed-plates have come into use, and they are probably suitable for paper made from weak fibres, which cannot stand the action of knives; provided, however, that the right kind of stone can be obtained.

The road which the pulp must travel over during one trip around the engine, is very different for different parts of the tub. While the pulp near the midfellow simply turns round the corner of that partition, the stuff which travels along the outside follows the outlines of the half circles at both ends.

In an engine-tub of $6\frac{1}{2}$ feet width and $15\frac{1}{2}$ feet length, for example, the midfellow would be about 9 feet long, and the pulp which moves close to it would go over a route of 18 feet length only, while that adjacent to the rim would have to travel over a distance of $18 + 20 = 38$ feet, or more than twice as far.

The pulp moves with nearly equal speed in all parts of a cross-section, and passes nearly twice as often under the roll near the midfellow than near the outside.

One might therefore suppose that the pulp should be beaten in half as much

time inside than outside; but if it were, it would hardly be possible to produce a uniform sheet of paper with our ordinary engines.

The engine, however, does not operate exactly in this manner. If, as we may for a moment suppose, twice as many rags were cut in the same time and with the same intensity near the midfellow as near the outside, the plate and fly-bars would become worn out in the same proportion in those places, and, after a short time, the distance between the knives would be such that the rags would not be ground at all where they pass often, and with great force where they pass less frequently. That this is actually the case is conclusively proven by the greater wear and tear of the plates near the front side of all engines with stationary back side bearings.

The pulp which is less frequently subjected to the grinding action of the roll is worked upon with proportionately increased intensity, and thus likewise transformed into fibres which can be formed into paper. The unequal treatment to which the different parts are subjected produces, however, fibres of very different length.

An engineer who uses the paddle frequently and with skill, can mix the pulp so, that the fibres throughout the whole mass change places, and a homogeneous pulp will be the result.

Fig. 26.

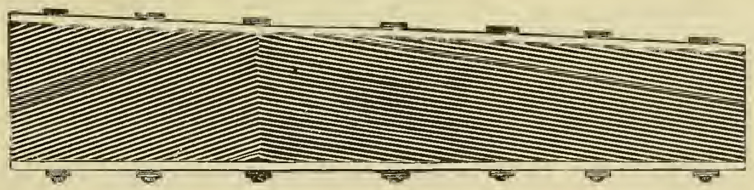


Fig. 27.

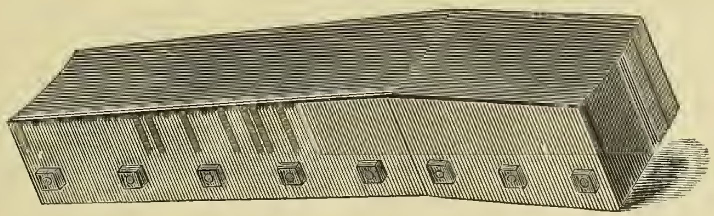
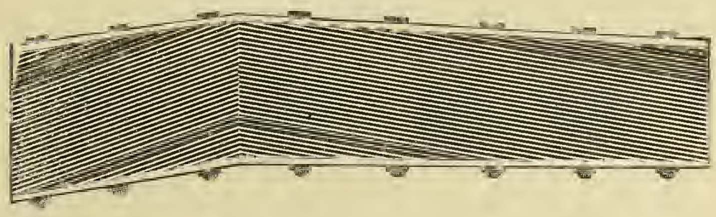


Fig. 28.



Every engineer, however, is not skilful and industrious, and improvements, which tend to simplify the operation of beating, are therefore very desirable.

Messrs. Nugent & Coghlan have received a patent of invention, dated July 30th, 1872, for improved bed-plates. Fig. 26 is a plan of one construction, and Figs. 27 and 28 view and plan of another.

The plates are larger at the front side of the engine than near the midfellow, and of the elbow form; but the forward point of the knives or the elbow is located at one-third of its width from the front end, instead of being in the middle, as usually.

The pulp, as shown before, does not pass as frequently over the plate at the front side as further back, but over more knives and a larger surface. The knives of the front part or short third of the plate form twice as large an angle or "shear" as the other two-thirds, and therefore cut sharper.

The knives, as well as the whole body of the plate, represented in Figs. 27 and 28, are of the elbow form, and thus present sharper angles or more "shear" than the others. Mr. Nugent prefers this latter kind.

The inventors speak of the advantages of their patent plates as follows:

> "Our improvement consists, first, in gradually increasing the number of knives in the bed-plate from the end adjacent to the midfellow to the end abutting against the outer wall or rim of the tub, so as to obtain a gradually increasing cutting surface from the inner to the outer end of the bed-plate, to compensate the difference in the number of times the stock in different parts of the tub passes over the bed-plate in a given time, the object being to produce pulp of uniform quality throughout the tub; second, in the employment of angular knives, the angle of which, or the line toward which they converge, is located nearest the outer wall of the tub, so that the increased velocity given to the stock, by drawing it rapidly toward this line, shall be made available in increasing the speed of the stock travelling near the wall or rim of the tub."

These patent plates are in operation at Messrs. Nugent & Co.'s mills, at Whippany, Morris County, New Jersey, which the author has visited. The screenings which were obtained from the pulp-dresser of each machine during one week were carefully gathered, and scarcely filled a hand-basin; while, as we were informed, two ordinary barrelfuls used to be collected during the same time, and from the same machine, before the introduction of the patent plates. Experience of this kind is the best evidence of the value of the invention, as it proves that a more uniform pulp is produced with the patent plates than with those of ordinary construction.

All these plates, of whatever material they may be made, must be raised whenever they are worn down too low, and, if not self-sharpening, they must be taken out and sharpened on a grindstone. Strips of wood or boards are usually put under the plates for the purpose of raising them.

It has also been proposed to keep the roll stationary, and raise the plate instead by means of an appropriate construction; but we have not learned that the plan has ever been carried out.

24. Grinding the Roll and Plate.—In a new engine, however well built, the roll never fits the bed-plate exactly, and it is necessary to grind them together before starting. This grinding has the additional advantage of flattening the sharp edges of both plates and fly-bars, so that they cannot cut the rags too severely. For this pur-

pose a board is fitted in on top of the highest point of the backfall, in such a way that nothing can escape from the roll in that direction. Another board, about a foot high, is fitted, for the same purpose, across the ascent which leads to the roll, as tight as possible. Water and hard sharp sand are then supplied to the roll between these boards, and the pulley started.

The sharp sand, reinforced by fresh additions, soon takes off the edges and projections. If none of the water and sand is allowed to escape beyond the board partitions, the engineer has little else to do but to lower the roll gradually until the sound indicates to him, by its uniformity, that the engine is all right. To make sure of it, he can introduce a sheet of paper under the roll, and, turning the pulley by hand, try if it cuts the paper all around and across.

25. Washing.—Washing engines consume large quantities of clean water, and the more the better. This water must be supplied through pipes, the diameter of which varies from 3 to 6 inches, according to the pressure with which it is forced, the size of the engine, and the capacity of the washers. It should, as soon as possible, become thoroughly mixed with the pulp by the action of the roll, and is therefore introduced at the end, where the rags ascend.

It enters the engine either from the top or bottom. In the first case, the flow of water is open to the eye, and additional filtering arrangements, such as flannel bags, can be used, through which it must pass before reaching the pulp.

If the water is admitted from below, it is more thoroughly mixed with the pulp, stirs up stragglers on the bottom, and displaces the dirty water, driving it to the top, where it finds itself in contact with the washers.

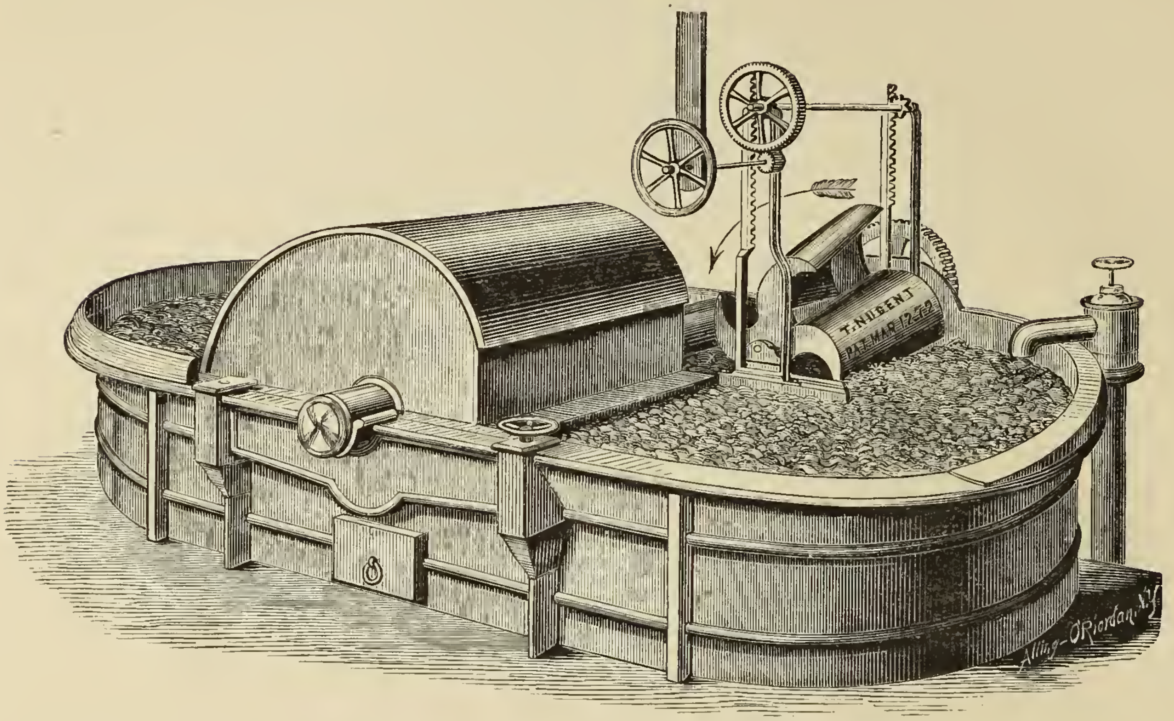
Provided that the water is well filtered before it reaches the engine, the latter system deserves the preference.

26. Circulation. Nugent's Pulp Propeller.—After the water and pulp have been thrown together over the backfall by the roll, they accumulate there until the additional quantities constantly arriving force them to move on. If the mass is very much diluted, it flows easily, like water, and the surface will be level all through the engine; but if, as is usually the case, the contents are not so fluid, some pressure is necessary to push them forward on their return trip. Thus the pulp accumulates sometimes behind the backfall, to stand 6 and more inches higher there than before the roll at the other end. The tub of an engine should therefore be built highest where the pulp leaves the roll, and from there descend in a straight line, following the sides, until it reaches the point where the pulp enters the roll, or to the cap.

If the engines are heavily loaded, 6 to 8 inches difference in height is hardly sufficient, while at other times not half of it will be reached. It is convenient to have 5 to 7 inches elevation for engines which carry from 400 to 500 pounds of pulp. Those which serve as washers only, may never be filled so high as to require it, but the pulp should always be thick in the beaters.

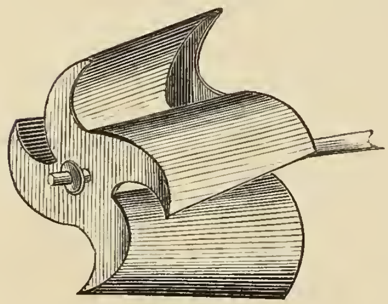
Messrs. Thomas Nugent & Co., of Whippany, Morris County, N. J., have

Fig. 29.



received a patent, dated March 12, 1872, for a *pulp propeller*, shown by Fig. 29 in working order, and by Fig. 30 removed from the engine.

Fig. 30.



It consists of two cast flanges, to which four curved brass wings or arms are fastened by means of countersunk screws. If any one of the arms should break, a new one can easily be put in its place, by simply turning out the screws and re-setting them with the new arm.

The inventors explain the use of the propeller and its advantages as follows:

"In the ordinary beating engines for making paper pulp, no automatic means is provided to give motion to the stock other than the knife-blades projecting from the surface of the beating roll or cylinder; and when first furnished, the stock, owing to its long state, moves so slowly in the engine that it requires to be propelled by the attendant with a stick or paddle, which, besides being a very laborious operation, is done in a very imperfect manner, for only a few minutes at a time. The want of an automatic propeller is still more felt when two kinds—hard and soft—of stock are used, in which case the hard stock lags behind and the soft or light stock floats ahead, making irregular pulp, unless the stock is constantly stirred by the attendant; and, in consequence of this slow motion and laborious work, the engine cannot be furnished to its full capacity.

"These difficulties are wholly overcome by the use of the propeller, which is driven by the ordinary mechanism used in driving the cylinder washer. The propeller may be set in motion as soon as the washing cylinder has performed the functions allotted to it, which will cause the stock to move with the desired velocity around and around in the vat, under the beating roll, until it has been properly reduced to pulp. The current is so much faster, and the stock is operated upon with so much greater regularity, by the use of this propeller, that it will be reduced to pulp in a much shorter space of time, and the product will be greatly improved in quality.

"The engine also can be furnished to its utmost capacity—carrying twenty-five per cent. more, and taking no more perceptible power. The roll-bars can be used until worn down very short, as you do not depend on the bars to draw the pulp under the roll.

"The tapering form of the propeller gives to the current of the stock a greater velocity along the outer wall of the engine, where it should travel the fastest."

The propellers, which we have seen in operation, seemed to accomplish what the inventors promise, for the engines were very heavily loaded and the stuff turned well.

Wherever it is deemed desirable to increase the capacity of the beaters, by loading them with a larger quantity of pulp than the roll alone can easily turn, a propeller will do good service.

27. Washing Cylinders and Syphons.—In former times, strainers in the cap of the engine, consisting of a flat wooden frame covered with wire-cloth, were used exclusively for washing; but they have been entirely superseded by washing cylinders. The rags or pulp are thrown with such violence against the strainer by the roll that a large quantity of fine fibres must go through it and be lost. It is not visible while at work, being incased in the cap, and large quantities of pulp may have been lost before a hole or break is discovered, if it should occur.

The dirtiest, coarsest rags are washed perfectly clean with cylinder washers alone in nearly every mill in the United States, and there is no reason why these wasteful strainers should not everywhere be entirely abandoned.

Most so-called cylinder washers have eight corners, and as many buckets, shaped with a view to lifting up the largest possible quantity of water, discharging it through the centre. They are sometimes made of copper and brass, but mostly have cast-iron shafts, and discharge centres, and wooden buckets.

The heads of each of the washers D D, Figs. 20 and 21, are of copper or boards, fastened to the centre or discharge piece, which is keyed on the shaft. The surface is formed of eight separate wooden frames, covered with a coarse brass wire-cloth, of about No. 3 or 4, which serves as a support to a finer one of about No. 60.

The washer shaft rests in two boxes attached to racks E, and can be raised or lowered in high stands by means of a shaft with pinions and crank F. When in the lowest position, a cog-wheel G, on the washer shaft, meets a stationary pinion which is driven by a pulley and belt, and thus causes the cylinder to revolve.

The washers usually met with may be much improved upon.

In most of those which we have seen, the buckets, for no apparent reason, are placed at a distance of 2 to 3 inches from the outside wire.

The space between the bucket and the wire is evidently lost, while it might be made useful by extending the former as close to the circumference as possible.

The discharge centres are often so narrow that the water cannot pass out as fast as it enters.

In *syphon washers* the shaft is a stationary pipe, from which several vertical branch pipes extend inside of the cylinder downwards nearly to the cover. A continuation of it descends several feet outside of the engine, and is provided with a stop-cock at the end.

The cylinder is built as light as possible, but strong enough to support the wire-cloth with which it is covered, and revolves on the immovable hollow shaft, propelled by the motion of the pulp only.

It is necessary to fill or prime the pipe, before the suction can be started, through a short pipe with stop-valve and funnel, which can be fed from the general water supply. After the syphon has been filled, the cock at the lower end is opened, the water escapes, creating a vacuum, which is refilled by the water inside of the cylinder. The liquid part of the pulp passes through the wire cloth, and thus flows away through the syphon in a constant stream, until it is prevented by some cause from entering the cylinder.

This happens sometimes when the stuff sticks to the wire-cloth and covers it with a coat of fibres. The syphon, not being fully supplied, empties itself, and cannot be started without being primed again. If it is not quickly discovered that the syphon has stopped working, the engine will be filled up by the wash water and ultimately run over.

This washer requires no gearing and recommends itself by simplicity, but the difficulty mentioned is, according to the author's experience, so serious that cylinders which are driven by power, and never stop work unexpectedly, deserve the preference.

The syphon may be connected with a pump or other artificial suction arrangement, and thus made to work at all times, but then the simplicity of the washer—its principal advantage—will be lost.

28. Hammond's Washer.—A washer which seems to overcome all these difficulties has been patented by George W. Hammond, manager of Cumberland Mills, and Thomas T. Foster, of Westbrook, Maine.

Fig. 31 represents a section parallel with the heads; Fig. 32 shows a section through X Y, and the following is the description as given by the inventors in the specification of their patent, dated April 16, 1872.

"A shows a rotating cylinder, covered with a network or gauze of wire as common, and rotating in the ordinary manner with the shaft B. C shows the buckets or scoops attached to the interior of the rotating cylinder, and which take up the water as the cylinder revolves. As the cylinder rotates, the buckets or scoops are carried around until they are so inclined as to empty their contents into the receiver or vat D, from which the said contents run out at the aperture E. The scoops or buckets C are of the form indicated in Fig. 31, and extend the whole width of the interior of the cylinder A to the inside of the walls F, to which they are bolted.

"In the old form in which this device was made the scoops were different in construction, and were made of wood. Moreover, their arrangement within the rotating cylinder was also unlike our invention. We make our scoops of metal (galvanized iron).

"The pan or receiver D is suspended on the central shaft B by the loose sleeves G and arms H, so that, notwithstanding the rotation of the cylinder, the receiver or pan always remains suspended,

Fig. 31.

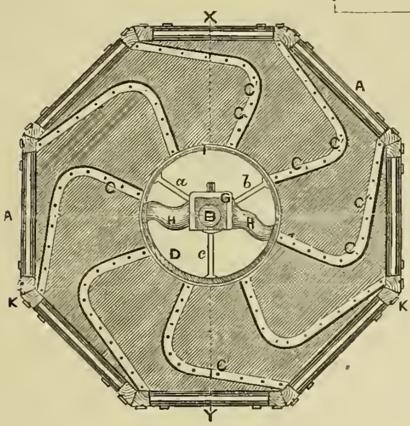
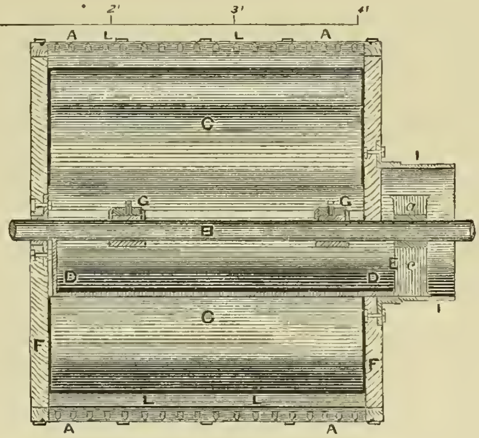


Fig. 32.



and is not carried around with the shaft B or the cylinder A. In consequence of this it will be seen that when the scoops or buckets C are carried by the revolution of the cylinder A, so that they or any of them occupy toward said cylinder the position of C′, they will then discharge or empty their contents into the said receiver D, from which the said contents pass away through the aperture, as at E, before set forth.

"The aperture E is formed by the projecting ring I attached to the exterior of one of the ends of the cylinder A. From the shaft B extend the arms *a b c* to the interior periphery of said ring I, thus carrying around the said cylinder with the revolution of the shaft B."

The only objection which might possibly be raised to this construction is that the receiver D might be carried around by the friction of the shaft B in the sleeves G. But this is overcome by making the receiver heavy at the bottom, and by filling the sleeves G with lignum vitæ, thus reducing the friction. Fig. 33 and Fig. 34 are

Fig. 33.

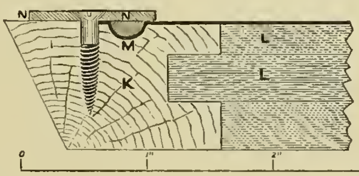
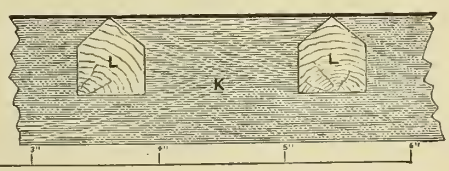


Fig. 34.



sections on a larger scale lengthway and across one of the eight windows or wire frames, which cover Mr. Hammond's washer. The outside of these wooden frames is formed by the pieces K, and the numerous pointed crosspieces L support the wire.

No tacks are used on these frames, but all around, where the wire is usually

fastened, a ridge M is cut out about $\frac{1}{8}$ inch deep and $\frac{1}{4}$ inch wide in the pieces K, and the wire spread over this excavation. A piece of brass fitting the channel M exactly is then pressed into it and held down by brass buttons or washers N, thus fastening the wire with a firm grasp.

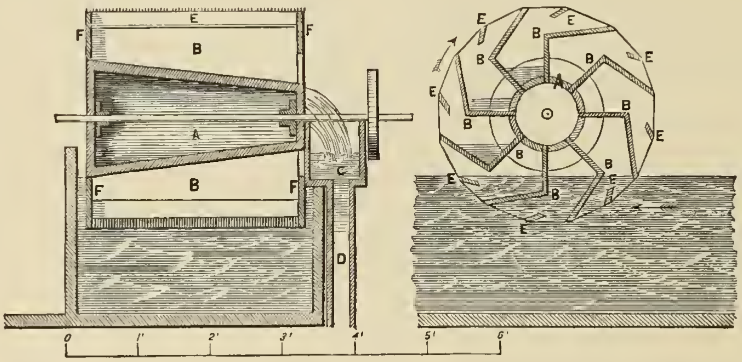
A number of these washing cylinders are in operation, and it is stated that one of them performs as much work as two of the ordinary kind. As far as we are able to judge from personal observation, we have no reason to doubt that such is the case.

The water-pipe, which used to supply two ordinary washers, is not sufficient to furnish a sufficient quantity of water for one of this kind.

29. Fox's Washer.—A washing cylinder, which for cheap construction and comparative efficiency surpasses all others known to us, is represented by sections length and crossway in Figs. 35 and 36, as drawn from memory. It has been built by Mr. Fox, millwright, and is in operation at Mr. Dexter's Star Mills, Windsor Locks, Connecticut.

It is a wooden cylinder with no iron in it besides the shaft. A solid cone A forms the centre, and the wooden buckets B have the usual form. They discharge

Fig. 35. Fig. 36.



all around the smaller end of the cone into the box C as soon as they have passed the centre line or the top of the box C. The side of this box next to the cylinder is placed so close to it, that it prevents any water from leaving the buckets until they pass it; but then it pours out in copious streams open to the sight, and leaves through the stationary discharge-pipe D. No frames are used, but strong wire about $\frac{1}{16}$ inch thick is wound around the buckets so as to leave only about $\frac{1}{2}$ inch space between the turns or circles. To sustain this wire there is an intermediate board E put in the middle between every two buckets, so that it rests on sixteen supports. The wire-cloth is directly spread over this wire frame, and fastened on the wooden head-boards F.

The buckets thus reach out to the wire, and the cone centre causes a quick discharge.

30. Efficiency of Washers.—The time, in which rags can be cleaned, depends prin-

cipally on the quantity of water which can be passed through the washers, so that an engine with two cylinders may accomplish nearly as much as two engines with one cylinder.

The washing cylinders are located on each side of the shaft, and driven either directly from it, or from a countershaft at the ceiling at a slow speed in the same direction as the pulp.

The deeper a washer dips into the pulp the more water is taken out, but if sunk too low, the flow of pulp will be obstructed. It is well to keep the engine as full as possible while washing.

Three feet diameter is the usual size of a washing cylinder, and at least 2 inches space must be left on each side between it and the sides of the engine.

These washers somewhat resemble a working cylinder, and it is only natural that short pasty pulp, such as old papers, straw, &c., furnish, sticks to the wire, and forms sheets on it, thus making it partially inactive. They can, however, easily be kept clear by means of a shower-pipe, fastened parallel to the shaft, a few inches distant from the wire, where it emerges from the pulp.

Most impurities are heavier than water, and have a tendency to sink to the bottom. If the engine is very deep, a large portion of the contents can pass below the washer, without coming in contact with it, and remain uncleaned.

Washing engines should therefore be always very shallow; their size may be increased in every direction except in depth.

A well-constructed engine with two washers will transform the dirtiest rags, if well boiled, &c., into clean pulp within two to four hours. As soon as the water runs off pure, the cylinders are hoisted up and the roll is let down sufficiently to draw out the rags and grind them into long half stuff.

31. Size of Engines.—Engines of all sizes are used, from those carrying 100 pounds to those of 1500 pounds; and it is an object of controversy among paper-makers which size is to be preferred.

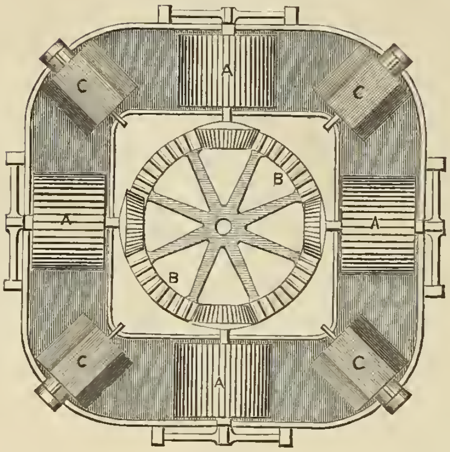
It is evident that one engine of 600 pounds takes less room, costs less to build, to put up, and to run, than two of 300 pounds; and there is no reason why an engine carrying 600, or even 1000 pounds, if built on correct principles, should not produce as good a pulp as one of 300 pounds.

The facts seem to bear out this opinion, as nearly every new mill contains larger engines than the one whose place it took. Few new ones are built of less than 400 pounds capacity, and the tendency is upwards to 600 and 800, and even 1500 pounds.

An engine with a roll of 3 feet width and a vat about 14 feet long and 6½ feet wide, 24 to 30 inches deep, carries from 350 to 450 pounds. A 4 feet roll and vat in proportion furnishes 600 to 750 pounds; and a 4½ feet roll in a vat 9½ feet wide and 22½ feet long constitutes a 1000 pounder. New engines, which have been constructed for some of the largest paper-making firms in this country, are of wood or iron, with rolls 5 feet wide, and capable of turning out over 1500 pounds of paper.

As a curiosity, we may mention an engine with four rolls, a plan of which is represented by Fig. 37. We have seen it in operation at Messrs. Campbell, Hall & Co.'s mill, near Norwich, Conn. The engine forms the four sides of a hollow square, with a roll A on each side, driven by a common wheel B in the centre. A washing cylinder C is placed in every corner. It only differs from four separate engines by not having a midfellow and by the flow of the pulp directly from one roll to another.

Fig. 37.



The object of this construction seems to be increased capacity; but it is impossible to make the four independent rolls work exactly alike, to keep the knives at the same degree of sharpness, and to raise or lower them one as much as the other. If this is not done, some of the four rolls will do all the work, while the rest are simply turning; and it is not to be wondered at that the engine does not give satisfaction.

32. Foundation.—Engines are heavy and hard working machines, which require a solid foundation. They are usually located in the second story, because they have to empty into chests or drainers below them; and as these drainers generally occupy all the available space, solid stone pillars can be used in few cases only. If the building is, at least up to the second floor, constructed of stone or brick, heavy timbers, about 12 by 16 inches strong, laid across these walls, and supported by posts, will make a good foundation. Three to five of them, parallel with the shaft, are enough to carry an engine.

Where expense is less an object than safety and durability, iron girders and pillars take the place of wood.

The engines, if not too small, are heavy enough to stand on these girders without other fastening than the floor, which is laid tight around the bottom, and keeps them in place.

It is easy to form an idea of the force which is always at work to vibrate or shake the foundation, by considering that every fly-bar passes every knife of the plate once in a revolution; or, supposing the engine to have 50 fly-bars, 15 bed-knives, and to run with 120 turns, it will make $50 \times 15 \times 120 = 90,000$ cuts per minute.

Anybody standing alongside of an engine working rope, with the roll down, will easily be convinced by the noise and vibration that the foundation can hardly be made too solid.

33. Discharge.—The discharge-valve (G in Fig. 18 or I in Fig. 20) should be as far distant as possible from the point where the water enters, so that it will sweep over most of the bottom before leaving the engine. The time required to empty an engine is lost, and a quick discharge desirable. The valve is therefore always a large

one—not less than 6 to 8 inches diameter. Smaller valves are also provided, through which the engine and sand-traps can be cleaned out. They are all of brass, with seats of the same metal, and when closed are flat with the bottom, so as to offer no obstruction; there is only a little cavity in the centre, with a strip across it, of which the engineer can get hold with an iron hook, while the engine is full.

The discharge-valve is connected with wooden spouts or copper pipes, through which the pulp is emptied. The larger these are, and the more fall they have, the better, because the pulp will not be obstructed, but flow away rapidly, and the engine be quickly cleared. For the same reason sharp corners are to be avoided as much as possible.

(b) *Bleaching.*

The rags are bleached: with liquids in the engine; with liquids in drainers; with gas.

34. Bleaching Powders.—The chemical which plays the principal rôle in our bleaching processes is commercially called bleaching salts or powders, and improperly also chloride of lime.

It is produced by introducing chlorine gas into hydrate of lime (slacked lime). In the manufacture of soda large quantities of hydrochloric acid are obtained, which would be nearly worthless if they could not be utilized in furnishing the chlorine for this substance.

In the United States there is an abundance of all the raw materials required by the soda-makers, but nevertheless, strange to say, with very poor economy, we allow ourselves to be permanently dependent on England for our supply of this important article, and consequently also of bleaching powders.

These powders were formerly supposed to be a combination in equal parts of the elements calcium Ca, the basis of lime, and chlorine gas Cl, and accordingly called chloride of lime. It has since been found that this is not the case, but that they consist of the elements calcium, oxygen, and chlorine, in equal quantities.

The combination of hypochlorite of lime with chloride of calcium,

$$CaO,ClO + CaCl$$

contains equal quantities ($2Ca + 2O + 2Cl$) of these three elements, and gives a satisfactory explanation of the chemical action of the powders.

It is therefore generally accepted that bleaching powders are a union of hypochlorite of lime and chloride of calcium; and Fresenius has found that they contain in addition some free chloride of calcium ($CaCl$), hydrated lime (CaO,HO), and water in variable quantities.

The chloride of calcium ($CaCl$) has a very strong affinity for water, absorbs it from the air with avidity, and not only increases the weight of the powders by so much water, but also assists, by this moisture, the decomposition of the valuable hypochlorite of lime.

Powders which are moist, without being commercially "in damaged condition,"

show thereby the presence of a large quantity of free chloride of calcium, and are, therefore, of poor quality.

The light has no influence on dry powders, but it transforms the valuable hypochlorite of lime in liquid solution into chlorite of lime (CaO,ClO_3) and chloride of calcium ($CaCl$), both of which have no bleaching qualities. It is therefore of importance that bleach-solution should be kept in the dark.

The air acts directly on the hypochlorite of lime by uniting its carbonic acid with the lime, setting the hypochlorous acid free, which in its turn separates into its elements chlorine and oxygen. This is the source of the strong chlorine smell which is always noticed in the presence of bleaching powders, and affects very violently our respiratory organs. Heat greatly promotes these changes, and especially the escape of chlorine gas.

Bleaching powders should be packed so that neither air nor moisture can reach them. They are generally shipped in casks, sometimes, from short-sighted economy, made of soft wood.

But even if the best hard wood is used, the air and moisture find access, as the changes of temperature cause cracks, through the contraction and expansion of the staves.

The pores of the wood are alone sufficient for communication between the inside and the air. A piece of iron lying in a store-room with bleach casks soon shows rust on its surface,—an evidence of the presence of chlorine in the atmosphere.

The staves are so strongly impregnated with the gas that, if burned under the boiler, the iron must in course of time suffer from it.

The lining of casks with good tough paper is a protection for the powders, but we would suggest that they should be covered inside with pitch, closing the pores, so as to be able to withstand the influence of chlorine.

Dishonest dealers not only sometimes sell wet and damaged bleaching powders as good ones, but even take advantage of the increase in weight, by whitewashing the original weight-marks and putting the new real weight in their place.

Purchasers should refuse any casks on which the original marks have been effaced or covered.

Bleaching powders must be stored in dry and moderately cool rooms; but they deteriorate with time, no matter how well they are taken care of.

The further a paper-mill is distant from where the powders are manufactured, the more care is to be taken to buy only the best brands, to get them with the least possible delay, and without allowing them to be stored anywhere. If purchased from dealers, the preference is to be given to casks yet on board or just landed, as it is impossible to tell how old they may be if taken from a warehouse.

35. Chemical Action of Bleaching Powders.—Dry chlorine gas may be ever so long in contact with a colored rag; it has no effect on it; but as soon as water is added it begins to bleach or destroy the color.

The action of the chlorine is due to its strong affinity for hydrogen. Whenever

chlorine meets a composition of which hydrogen forms a part, it draws the latter irresistibly towards itself, combining with it to produce hydrochlorous acid, ClH.

If both these gases, however, are put together in a bottle, they remain separate as long as they are kept in the dark, but as soon as light is admitted they unite with such a force that an explosion is heard.

It is daily demonstrated by bleaching in rotary boilers that light is not indispensable for bleaching, but the experiment mentioned seems to indicate that its presence is at least useful.

Water is a union of one atom of oxygen O with one of hydrogen H, and forms with chlorine hydrochloric acid HCl and free oxygen O.

$$\underset{\text{Chlorine.}}{Cl} + \underset{\text{Water.}}{HO} = \underset{\text{Hydrochloric acid.}}{HCl} + \underset{\text{Oxygen.}}{O}$$

This oxygen, at the moment when it emerges from its connection with other elements, or, scientifically expressed, in its nascent state, destroys all the colors which have hydrogen in their composition, or admit of a higher oxidization. The addition of this oxygen to such colors compels new formations, in which it is mostly united with hydrogen as water.

Vegetable fibres and all colors of organic origin are composed of carbon, oxygen, hydrogen, and sometimes nitrogen; they cede their hydrogen to oxygen in the nascent state, and are thus decomposed and discolored.

Oxygen which has been produced in the ordinary way has no bleaching power whatever, but if exposed to the continued influence of the electric spark it acquires a strong and characteristic odor and different qualities from those it had before. This discovery was made by Professor Schoenbein, and the oxygen in that condition called by him "ozone," which is the Greek word for "smell." It has strong bleaching properties, and it is supposed that oxygen in its nascent state has the qualities of ozone. The colors always succumb first to its attacks, but if the bleaching is continued, or an excess of chlorine used, the fibres will also be destroyed.

A solution of bleaching powders in water contains all their hypochlorite of lime and chloride of calcium, of which the hypochlorous acid is the only valuable part. Its component elements, chlorine and oxygen, form a very loose partnership, and the connection with lime is hardly any more binding. This is so much so that the chlorine in the hypochlorous acid acts nearly as if it were simply dissolved in water. It only takes a longer time to drive it out or exhaust it, as a certain, however weak, resistance must be overcome.

The chlorine in the chloride of lime can be driven out by acids, and, like the chlorine which has been obtained from the hypochlorite of lime, decomposes water, but the resulting oxygen is taken up by the calcium to form lime or oxide of calcium.

$$\underset{\text{Chloride of calcium.}}{CaCl} + \underset{\text{Sulphuric acid.}}{SO_3,HO} = \underset{\text{Sulphate of lime.}}{CaO,SO_3} + \underset{\text{Hydrochloric acid.}}{HCl}$$

The chloride of lime can therefore not be made available for bleaching.

Each atom of chlorine in hypochlorous acid not only liberates one atom of oxygen from water, but the atom of oxygen with which the chlorine had been united is also set free, so that for every atom of hypochlorous acid two of bleaching oxygen are obtained.

$$ClO + HO = HCl + 2O$$

Every two atoms of chlorine which are consumed in the manufacture of bleaching powders must waste one in useless chloride of calcium, but the other atom of chlorine in the hypochlorite of calcium makes up for it by developing double its quantity of bleaching oxygen.

Bleaching powders, if of full strength, thus return one atom of bleaching oxygen for every atom of chlorine which has been used in its preparation, and may simply be considered a convenient vehicle or reservoir for the transportation of chlorine gas.

36. Strength and Test of Bleaching Powders.—The atomic weights or equivalents of the three elements, supposed to form the principal part of the bleaching powders in equal parts, are—

Calcium, ...	Ca	=	20
Chlorine, ...	Cl	=	35.46
Oxygen, ...	O	=	8
			63.46

or altogether 63.46, of which about 56 per cent. are chlorine.

In this calculation the free chloride of lime, hydrate of lime, and the inevitable and variable quantity of water, are not taken into account, and reduce the percentage of free chlorine considerably. Only one-half of all this chlorine, or the part which is contained in the hypochlorous acid, is free chlorine, but as every atom of it develops two of bleaching oxygen, it is counted double.

Thirty-two per cent. is considered the standard strength by the trade, and powders testing less should not be accepted as good delivery. Powders of 38 to 39 per cent. are the strongest usually offered.

Since their value is altogether based on the hypochlorous acid or "free chlorine" which they contain, it is of the utmost importance to ascertain its quantity.

Every manufacturer of powders sends with the invoice a certificate stating that samples of the lot contained a certain percentage of free chlorine on a certain day before it was shipped. Supposing that this test was correct, there is no guarantee in it that since they were made, and before the purchaser received the goods, a large portion, perhaps most, of the free chlorine may not have escaped. It becomes, therefore, necessary to test again.

There are in every large city analytical chemists who make these tests their business, and if they are able and honest men it is better for the purchaser to trust them with the examination than to make it himself. The chemist has more experience and all the requirements for the work, and his testimony as that of a third disinterested party is of value.

Some manufacturers may, however, for their own experience and instruction, prefer to make the tests themselves, and for their benefit we will describe the process which is at present considered the most convenient and reliable one.

First weigh off a quantity of the bleaching powders, say, for instance, five grammes; dissolve it in water, and separate the liquid from the insoluble part by filtration. The insoluble part consists of hydrate and carbonate of lime, CaO,HO and CaO,CO_2, and remains on the filter. Wash it out, and add enough water to fill 1000 cubic centimetres or any other fixed volumes with it.

Secondly, a solution of arsenious acid in hydrochloric acid is to be made. The arsenious acid must be carefully weighed; and we will suppose that 2970 grammes have been used. Add again enough water to fill another 1000 cubic centimetres or volumes with this solution, which may be bottled for many such tests until used up.

Pour, for our example, 50 cubic centimetres of it into a good-sized beaker-glass, and add enough tincture of indigo (a solution of indigo in sulphuric acid) to color the liquid blue.

Drop slowly into this blue solution, from a graduated burette, enough of the liquid made from the bleaching powders to destroy the blue color. As soon as it disappears, stop and read off how much of the chlorine solution has been used.

This test is based on the bleaching or oxidizing power of the free chlorine or hypochlorous acid in the powders. The hypochlorous acid in contact with water and vegetable matters develops oxygen, which is rapidly absorbed by the arsenious acid. As soon as all the arsenious acid (AsO_3) has been thereby transformed into arsenic acid (AsO_5),

$$\underset{\text{Arsenious acid.}}{AsO_3} + \underset{\text{Water.}}{HO} + \underset{\text{Hypochlorous acid.}}{ClO} = \underset{\text{Arsenic acid.}}{AsO_5} + \underset{\text{Hydrochloric acid.}}{HCl},$$

the free chlorine destroys the blue indigo color, and indicates that as much oxygen has been set free as the arsenious acid could absorb.

The atomic weight or equivalent of arsenious acid is

Arsenic, ...	As	=	75
Oxygen, O = 8	O_3	=	24
	AsO_3	=	99

Arsenious acid (AsO_3) requires two atoms of oxygen, or two of chlorine in the powders, to oxidize it into arsenic acid (AsO_5).

The atomic weight of chlorine is 35.5, and of two atoms $2 \times 35.5 = 71$.

The 50 cubic centimetres of the arsenious solution represent $\frac{1}{20}$ of 2.970 or 0.1485 grammes, and the quantity of chlorine which has been used for them stands to 0.1485 in the same proportion as its atomic weight 71 to that of arsenious acid 99.

$$\frac{0.1485 \times 71}{99} = 0.1065 \text{ grammes}$$

is therefore the weight of chlorine which has been used to oxidize the 0.1485 grammes of arsenious acid.

Supposing, now, that of the 5 grammes or 1000 cubic centimetres of bleaching powders, 62.5 cubic centimetres or

$$\frac{5 \times 62.5}{1000} = 0.3125 \text{ grammes}$$

have been used, they contain 0.1065 grammes or

$$\frac{0.1065}{0.3125} = 34.08 \text{ per cent. of bleaching chlorine.}$$

To make these tests correctly, not only good scales, pure chemicals, distilled water, &c., but also careful handling, such as can only be acquired by experience, are necessary.

37. **Bleach Solution.**—The powders always contain an insoluble portion of hydrate of lime, carbonate of lime, stone, and dirt, which would remain mixed with the pulp if the powders were used on it directly. By bleaching with a solution these impurities are kept out.

As chlorine attacks and destroys iron or wood, these solutions have to be made either in wooden tubs lined with lead, or better, in cisterns built of brick and cement, in the manner described hereafter for drainers.

In mills where large quantities of powders are used—say, for instance, 800 to 1000 pounds every one or two days—these cisterns should be large enough to dissolve the contents of a hogshead. The handling and weighing or measuring of these powders is extremely disagreeable and unhealthy; they pervade the atmosphere, and thus enter the respiratory organs, which cannot fail to be affected by them. A large sponge tied before mouth and nose gives only imperfect protection to the operative, and it is pardonable if he does the work in a hurried and perhaps imperfect manner. The gross weight and the tare are marked on every hogshead, and may be verified by direct weighing before it is opened. On those of English manufacture the weight is represented by three figures, the first of which gives the number of quintals equal to 112 lbs., the second the number of fourths of quintals or 28 lbs., and the third the number of single pounds. Gross weight and tare stand above one another, in the following manner:

$$\begin{array}{lll} 8, & 3, & 19. \\ 1, & 0, & 23. \end{array}$$

The upper figures of this example, representing the gross weight, sum up to:

$$\begin{array}{rcrcr} 8 & \times & 112 & = & 896 \\ 3 & \times & 28 & = & 84 \\ 1 & \times & 19 & = & 19 \\ \hline & & & & 999 \end{array}$$

The lower figures or tare are:

$$\begin{array}{rcrcr} 1 & \times & 112 & = & 112 \\ 1 & \times & 23 & = & 23 \\ \hline & & & & 135 \end{array}$$

and the net weight, $999 - 135 = 864$ pounds.

If the cistern is calculated to dissolve 1000 pounds of powders, and the hogshead contains only 700 pounds, the quantity of water used with it must be reduced in proportion, or to $\frac{7}{10}$, so that the strength of the liquor may be as uniform as possible.

Two cisterns A A of about 8 feet diameter, as nearly circular as possible, and 5 feet deep, will be sufficient for this purpose; they must be furnished with iron or brass agitators, moved by belts and cog-wheels, as represented, at $\frac{1}{64}$ of the real size or $\frac{3}{16}$ inch per foot, by section and plan, in Figs. 38 and 39. One or two horizontal arms C, with about six to eight 1 inch rods of 2 feet length fastened upright in them, and reaching within 2 inches from the bottom, turning about 20 times per minute, make up the agitator. The hogshead having been emptied into one of the cisterns, the latter is filled up with water in proportion to the weight of powders, and the agitator set going by means of the clutch and lever D. Heat accelerates the solution, but facilitates the escape of chlorine gas. Though a steam-pipe may be provided, it is advisable not to use it, except to make the water lukewarm in winter. After the agitator has been running about three to six hours, it must be stopped to let the lime and impurities settle to the bottom. As soon as the liquid is perfectly clear it is drawn off through pipes E and F into a receiver B. The pipe F, which ends with a stop-cock, is fastened into the brick wall of the cistern A, and conveys the solution into the receiver; it connects with E, where it reaches the inside of the cistern by means of a joint, which is represented at $\frac{1}{8}$ of the real size, or $\frac{1}{8}$ inch per inch, by views and section, in Figs. 40, 41, and 42.

This joint consists of two elbows G and H fitted into one another, like a valve and its seat, and held together by the set-screw I. It is fastened to the cast plate L by a nipple K, which is screwed into it, and with which elbow G and pipe F are also connected. The form of the casting L, with its two projections holding the joint, can be seen from the drawing; it is held to the wall by bolts, and can be renewed if necessary. The pipe E can be turned up and down in this elbow-joint so that its inlet stands at any height of the cistern, and the clear liquor can thus be drawn off to any desired point. It is held or suspended in these positions by a rod or chain fastened to its upper end. While the agitator is in motion the pipe E stands upright, close to the wall, the revolving arms not being long enough to touch it.

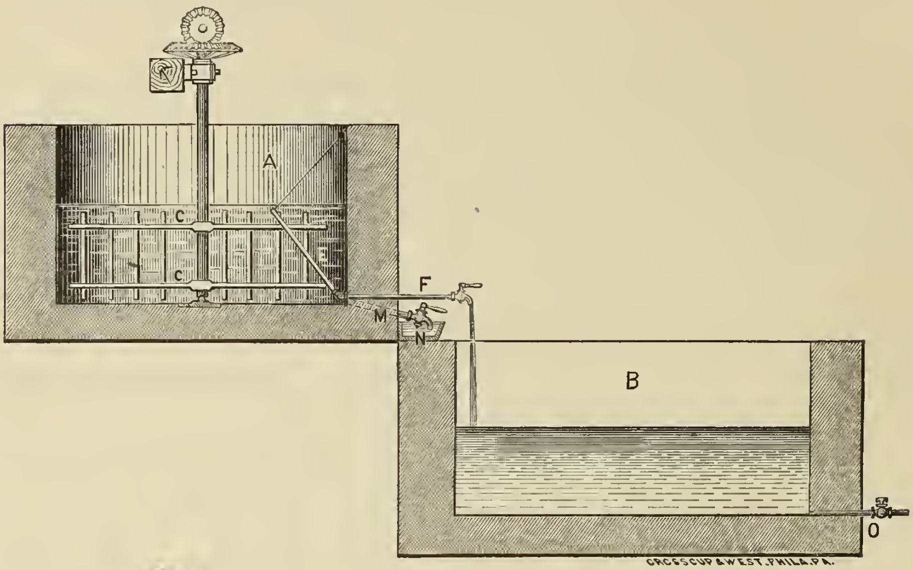
The casting L, elbows, and pipes are mostly of cast iron, and must be often renewed. Brass would withstand the action of the chlorine, and probably prove cheaper in the long run. The outside pipe F may be a lead one.

After the clear liquor has all been drawn off by gradual lowering of the pipe E, the cistern is filled up again with water, another solution is made like the first one, and also emptied into the receiver B.

While the second or weak extract is made in one cistern, a new portion of powders is dissolved in the other. Thus there are always a weak and a strong solution on hand at the same time, and good care must be taken to empty them together into the receiver, as otherwise the liquor would not be of the regular strength.

Some manufacturers use three cisterns and make three extracts from the powders to exhaust them thoroughly.

Fig. 38.



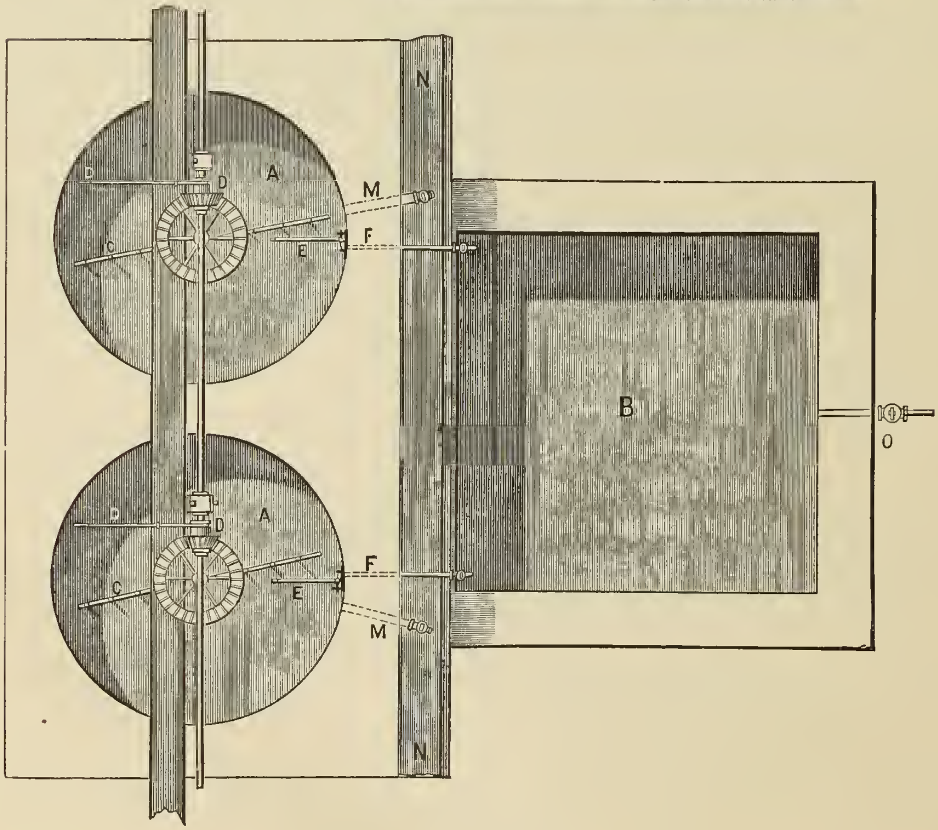


Fig. 39.

The impurities or sediment remaining on the bottom of the cisterns are washed out through the large lead pipe M, and carried off by the spout N.

The liquor in the receiver can be kept at the regular strength by diluting each solution until it shows the prescribed specific gravity on the hydrometer.

The cisterns and receiver should be kept as much as possible in the dark, and the solution not exposed to the air any longer than can be helped, as it continually loses in strength under the influence of light and air.

Fig. 40.

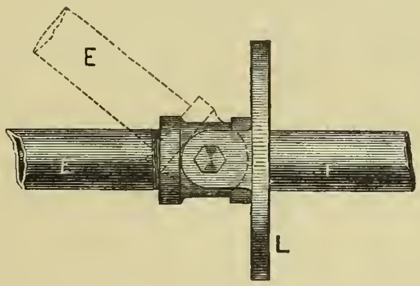


Fig. 41.

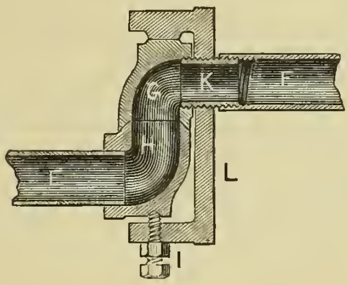
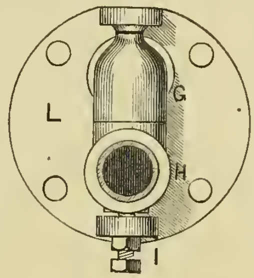


Fig. 42.



38. Strength of the Solution.—Chlorine is much heavier than water; every additional quantity of it in a solution increases the specific gravity—that is, makes it so much heavier than the same volume of water.

The hydrometers used by the paper-maker sink to zero in water; but if immersed in heavier liquids, they show more of their length above the surface, because, like all other solid bodies, they can only displace a quantity of liquid the weight of which is equal to their own. Hydrochloric acid and chloride of lime have no bleaching power, but increase (in a much smaller proportion than chlorine) the specific gravity of the solution, and the hydrometer does not therefore give a correct test. It is, however, the only handy one we have, and practically sufficient.

Whichever of the different hydrometers, named after their designers, is used, the liquor in the receiver should show always the same number of degrees, so that the same quantity may be expected to give the same result.

After the pulp has been washed and transformed into half stuff in the engine, a certain quantity of liquor is drawn from the receiver B through the pipe O, and added to it.

A considerable quantity of bleach-liquor must be kept on hand, exposed to the

air and perhaps to the light, and an inevitable loss of bleaching chlorine is thereby sustained. We prefer, especially for rags which require comparatively small amounts of bleaching materials, the following method:

39. Preparation of a Fresh Bleach Solution for every Engine of Pulp.—Every paper-mill uses oil, and has consequently empty oil-barrels of but little value. Take one of these, and cut it off about 8 inches from the head and parallel with it, so that it will make a good-sized tub. If a vessel, which chlorine does not affect, is preferred, a wooden box lined with lead answers the purpose. Set this box or tub on a platform close to the engine, and introduce a few inches above the bottom a faucet, through which the liquor can be drawn off.

Put the quantity of powders required to bleach one engine of rags (4 to 10 pounds per 100 pounds of paper) into the box; fill up with water, and make a solution by stirring it with a paddle. The faucet being high enough above the bottom, the clear liquor can, after it has had time to rest, be drawn off into the engine without disturbing the sediment. The dregs are taken out, dissolved in another barrel, and the weak solution obtained from them is added directly to the pulp in the next engine.

Whenever a new hogshead of powders is opened, the first liquor is made with the usual quantity, and must be tested with the hydrometer. The test indicates whether the powders are of the usual strength, or if the quantity used for each engine must be larger or smaller to obtain a solution of the usual strength. A barrel like the one described, of about 25 to 30 gallons capacity, containing 16 to 20 pounds of good bleaching powders, will give a liquor testing 6 to 8 degrees of Baumé's hydrometer.

This is certainly the cheapest way of dissolving and using bleaching powders, inasmuch as it requires no room and expense for bleaching-tanks, furnishes always a fresh solution, exhausts the powders thoroughly, and gives the control of the whole process to the engineer, who is the proper man to have it.

40. Vitriol.—Hypochlorous acid has, as said before, only a slight affinity for lime, and is easily driven from it by any stronger acid, for instance, sulphuric acid. It is true that the chlorine exhausts itself by bleaching the pulp slowly without acid, if enough time is allowed for it; but if the rags are very dark or coarse, and require much bleaching, the time and consequently the number or capacity of the pulp-receivers which would be needed, increase so much that the use of acid becomes a necessity.

The sulphuric acid forms sulphate of lime with the lime formerly connected with the hypochlorous acid, and the chlorine remains in the solution as hydrochloric acid. The process is represented by the following equation:

$$\underset{\text{Sulphuric acid.}}{SO_3HO} + \underset{\text{Hypochlorite of lime.}}{CaOClO} = \underset{\text{Sulphate of lime.}}{CaOSO_3} + \underset{\text{Hydrochloric acid.}}{HCl} + \underset{\text{Oxygen.}}{2O}$$

The two atoms of oxygen appearing in it are used up in bleaching.

The lime to which the sulphuric acid allies itself, joins the hydrochloric acid if the stronger sulphuric acid is not present. It forms with it chloride of calcium, according to the following equation:

$$\underset{\text{Lime.}}{CaO} + \underset{\text{Hydrochloric acid.}}{HCl} = \underset{\text{Chloride of calcium.}}{CaCl} + \underset{\text{Water.}}{HO}$$

The chloride of calcium is harmless, but the free hydrochloric acid acts on the pulp, and injures the color by turning it gray or yellow.

Bleach-liquor which has once been treated with vitriol, and consequently has considerable quantities of free hydrochloric acid, HCl, in solution, should not be again used on white pulp, or for the preparation of fresh solution. It is better to let it act by itself on unbleached pulp, which it will whiten by means of any remaining free chlorine.

Paper-makers who work the better grades of rags, and are supplied with plenty of drainer room, bleach generally without acid, but let the contents of the bleaching-engine remain in the drainers for 24 to 48 hours before allowing the liquid to drain off. This waste bleach solution may be used for the preparation of a new one, but in mills where the quality of the paper is more important than anything else, and where only white rags are used, as, for instance, in our fine writing-paper mills, it is allowed to run away.

Sulphuric acid or sulphate of water, commonly called oil of vitriol, is, if pure, a dense, colorless, inodorous liquid of an oleaginous appearance and strongly corrosive. When pure, and as concentrated as possible, its specific gravity is 1.845, and it contains then about 18 per cent. of water. The commercial acid is seldom of full strength, has generally a specific gravity of about 1.8433, and contains about 22 per cent. of water.

The quantity of impurities in it can easily be ascertained by evaporating some of the acid. If more than a trifling quantity of solids remains behind, the vitriol is not of good quality.

The pure hydrated acid of a specific gravity of 1.845 contains one atom of dry acid to one of water, SO_3HO.

The atomic weight or equivalent of sulphur is 16
" " " " oxygen 8
" " " " hydrogen 1

$$\begin{aligned} \text{And the relative weight of dry acid } SO_3 &= 16 + 3 \times 8 &= 40 \\ \text{water } HO &= 1 + 8 &= 9 \\ & & \overline{49} \end{aligned}$$

which brings the atomic weight of hydrated acid or sulphate of water to 49.

The ordinary commercial acid (specific gravity 1.8433) consists of one equivalent of dry acid and one and a quarter of water.

The specific gravity of any sulphuric acid is easily found with the aid of the hydrometer.

Table for Liquids Heavier than Water: giving the Specific Weights Corresponding with the Degrees of Baumé's Hydrometer.

Degree of Hydrometer.	Specific Gravity. By Baumé.	Degree of Hydrometer.	Specific Gravity. By Baumé.	Degree of Hydrometer.	Specific Gravity. By Baumé.	Degree of Hydrometer.	Specific Gravity. By Baumé.
0	1.0000	19	1.1504	38	1.3559	57	1.6446
1	1.0070	20	1.1596	39	1.3686	58	1.6632
2	1.0141	21	1.1690	40	1.3815	59	1.6823
3	1.0213	22	1.1785	41	1.3947	60	1.7019
4	1.0286	23	1.1882	42	1.4082	61	1.7220
5	1.0360	24	1.1981	43	1.4219	62	1.7427
6	1.0435	25	1.2082	44	1.4359	63	1.7640
7	1.0511	26	1.2184	45	1.4501	64	1.7858
8	1.0588	27	1.2288	46	1.4645	65	1.8082
9	1.0666	28	1.2394	47	1.4792	66	1.8312
10	1.0745	29	1.2502	48	1.4942	67	1.8548
11	1.0825	30	1.2612	49	1.5096	68	1.8790
12	1.0906	31	1.2724	50	1.5253	69	1.9038
13	1.0988	32	1.2838	51	1.5413	70	1.9291
14	1.1071	33	1.2954	52	1.5576	71	1.9548
15	1.1155	34	1.3072	53	1.5742	72	1.9809
16	1.1240	35	1.3190	54	1.5912	73	2.0073
17	1.1326	36	1.3311	55	1.6086	74	2.0340
18	1.1414	37	1.3434	56	1.6264	75	2.0610

Table by Ure: giving the Weight of Hydrated Acid $SO_3(HO)$ and that of Dry Acid SO_3 in One Hundred Weight of Commercial Acid of a Specific Gravity, which has been Found by the Aid of Baumé's Hydrometer and the Preceding Table.

Sp. Gr.	Liquid Acid in 100.	Dry Acid in 100.	Sp. Gr.	Liquid Acid in 100.	Dry Acid in 100.	Sp. Gr.	Liquid Acid in 100.	Dry Acid in 100.	Sp. Gr.	Liquid Acid in 100.	Dry Acid in 100.
1.8485	100	81.54	1.6520	75	61.15	1.3884	50	40.77	1.1792	25	20.38
1.8475	99	80.72	1.6415	74	60.34	1.3788	49	39.95	1.1706	24	19.57
1.8460	98	79.90	1.6321	73	59.52	1.3697	48	39.14	1.1626	23	18.75
1.8439	97	79.09	1.6204	72	58.71	1.3612	47	38.32	1.1549	22	17.94
1.8410	96	78.28	1.6090	71	57.89	1.3530	46	37.51	1.1480	21	17.12
1.8376	95	77.46	1.5975	70	57.08	1.3440	45	36.69	1.1410	20	16.31
1.8336	94	76.65	1.5868	69	56.26	1.3345	44	35.88	1.1330	19	15.49
1.8200	93	75.83	1.5760	68	55.45	1.3255	43	35.06	1.1246	18	14.68
1.8233	92	75.02	1.5648	67	54.63	1.3165	42	34.25	1.1165	17	13.86
1.8179	91	74.20	1.5503	66	53.82	1.3080	41	33.43	1.1090	16	13.05
1.8115	90	73.39	1.5390	65	53.00	1.2999	40	32.61	1.1019	15	12.23
1.8043	89	72.57	1.5280	64	52.18	1.2913	39	31.80	1.0953	14	11.41
1.7962	88	71.75	1.5170	63	51.37	1.2826	38	30.98	1.0887	13	10.60
1.7870	87	70.94	1.5066	62	50.55	1.2740	37	30.17	1.0809	12	9.78
1.7774	86	70.12	1.4960	61	49.74	1.2654	36	29.35	1.0743	11	8.97
1.7673	85	69.31	1.4860	60	48.92	1.2572	35	28.54	1.0682	10	8.15
1.7570	84	68.49	1.4760	59	48.11	1.2490	34	27.72	1.0614	9	7.34
1.7465	83	67.68	1.4660	58	47.29	1.2409	33	26.91	1.0544	8	6.52
1.7360	82	66.86	1.4560	57	46.48	1.2334	32	26.09	1.0477	7	5.71
1.7245	81	66.05	1.4460	56	45.66	1.2260	31	25.28	1.0405	6	4.89
1.7120	80	65.23	1.4360	55	44.85	1.2184	30	24.46	1.0336	5	4.08
1.6993	79	64.42	1.4265	54	44.03	1.2108	29	23.65	1.0268	4	3.26
1.6870	78	63.60	1.4170	53	43.22	1.2032	28	22.83	1.0206	3	2.446
1.6750	77	62.78	1.4073	52	42.40	1.1956	27	22.01	1.0140	2	1.63
1.6630	76	61.97	1.3977	51	41.58	1.1876	26	21.20	1.0074	1	0.8154

Vitriol is commonly shipped in large glass bottles, holding about 140 to 200 pounds, which for protection are boxed up in wood, and called carboys.

Vitriol should never be used otherwise in paper-mills than in a very diluted state, but the mixture with water must be made with some caution. It attracts water with great avidity, and must therefore be kept well closed, so that the humidity of the air cannot weaken it. Water and vitriol unite with such violence that the mixture, if made suddenly, becomes heated, and sometimes is sprinkled about, or even bursts the vessel in which it is contained. Accidents have often been caused by pouring a large quantity of water into vitriol, which might have been avoided by adding the acid very gradually to the water, and stirring constantly while doing so.

After the bleach-solution has been thoroughly mixed with the pulp during not less than ten to twenty minutes, the diluted acid is slowly added.

If poured in suddenly, more chlorine is developed than the liquid is able to take up; the surplus escapes into the air, and injures the lungs of the workmen instead of bleaching the pulp.

If the diluted vitriol is kept in a lead-lined box or earthen vessel somewhere above the engine, and admitted through a small lead-pipe only, it will be impossible for the engineer to pour it in too fast.

The sulphuric acid takes the place of hypochlorous acid (which, as soon as disengaged, bleaches the pulp in the manner described), and forms sulphate of lime, commonly known as gypsum, with the abandoned consort of the hypochlorous acid.

One atom of pure sulphuric acid unites with one atom of lime and forms one of sulphate of lime.

One hundred pounds of bleaching powders of 35 per cent. produce an amount of bleaching oxygen corresponding with or equivalent to 35 pounds of free chlorine. That quantity of chlorine is contained in the powders, but, as has been shown before, one-half of it is quite inactive, as chloride of calcium, CaCl, and the other half as hypochlorite of lime, CaO,ClO, sets free two atoms of bleaching oxygen for every one of chlorine.

While, therefore, the bleaching power, or a quantity of oxygen, corresponding with 35 pounds of free chlorine, is really furnished, it is done by only one-half of that amount in the hypochlorous acid, ClO, equal to $17\frac{1}{2}$ pounds.

It is not correct to say that powders of 35 per cent. contain that quantity of *free* chlorine, though the $17\frac{1}{2}$ per cent. are sufficient to produce an amount of bleaching oxygen corresponding with 35 per cent. To disengage from the hypochlorous acid of 100 pounds of powders the $17\frac{1}{2}$ pounds of chlorine which form its basis, one atom of dry sulphuric acid, or one atom of its basis sulphur is required for every atom of the basis chlorine.

One hundred pounds of commercial vitriol of 66 degrees Baumé, corresponding (see table on page 68) with a specific gravity of 1.8312, contain, according to our second table (page 68) about 76.00 per cent. of dry acid. Dry sulphuric acid consists of one atom of sulphur and three of oxygen, SO_3; the atomic weight of sulphur is 16,

and that of three atoms of oxygen, 3 times 8 or 24, and the proportion of sulphur in dry acid is as 16 in $16 + 24 = 40$ or $\frac{16}{40} = \frac{2}{5}$ of its weight. One hundred pounds of commercial acid, equal to 76.00 pounds of dry acid, contain, therefore, $76 \times \frac{2}{5} = 30\frac{2}{5}$ pounds of sulphur.

The atomic weight of sulphur is 16 and that of chlorine $35\frac{1}{2}$, which means that 16 pounds of sulphur will replace $35\frac{1}{2}$ pounds of chlorine, atom for atom.

The weight of sulphur which is required to replace $17\frac{1}{2}$ pounds of chlorine, atom for atom, is therefore—

$$\frac{17.5 \times 16}{35.5} = 7.887 \text{ pounds of sulphur.}$$

One hundred pounds of commercial vitriol contain $30\frac{2}{5}$ pounds of sulphur, and the 7.887 pounds of sulphur, equivalent to $17\frac{1}{2}$ pounds of chlorine, in 100 pounds of powders, are the basis of—

$$\frac{7.887 \times 100}{30.4} = 25.8 \text{ pounds of vitriol of } 66°.$$

This means that 25.8 pounds of ordinary vitriol will force out of 100 pounds of good powders all the bleaching power contained in them, or one pound of vitriol to every four pounds of powders is the largest quantity which should ever be used.

Any amount above this proportion would be wasted, and, if increased too much, may attack the fibres.

It has been shown before that the hypochlorous acid can be exhausted without the use of vitriol, if plenty of time is given to the process.

The quantity of vitriol used may therefore vary between nothing and one pound for every four pounds of powders, according to the quality of the stock, available drainer-room and time.

Some paper-makers prefer to use alum or rather aluminous cake in place of vitriol, because it gives the same result without any loss of chlorine gas.

Aluminous cake or alum is a combination of alumina (clay) and sulphuric acid, and as it takes some time to dissolve and decompose it in the pulp, its action is necessarily slow, and the chlorine is produced in quantities, which can be gradually used up as they appear.

The sulphuric acid in the alum is alone of any use, and the best brands contain hardly half of their weight in vitriol. Two pounds of it are therefore required, to do the work of one pound of pure acid.

The market price of alum is nearly twice that of vitriol, and four dollars will buy only one dollar's worth of acid in the shape of sulphate of alumina.

If the vitriol is diluted with a large quantity of water, and gradually added to the pulp, it will not be found necessary to have recourse to the costly alum.

(c) *Draining.*

41. Drainers.—As soon as the vitriol has had time to become thoroughly mixed with the pulp, the engine may be emptied into a drainer.

These receptacles for pulp are sometimes of wood, and will then soon be destroyed by the action of the bleach-liquor. Though their first cost may be low, they will prove more expensive in the long run than permanent stone ones, and can only be recommended in exceptional cases.

They are usually built on one of the two following distinct plans, and should be of brick and cement only.

They are either constructed so that the pulp can be emptied from the open top, or they have a door on one side, near the bottom, through which the pulp is taken out.

On the first plan they are situated in rows near the beaters, and at such height that the pulp can be thrown up on a platform, not far below or level with the floor of the engine-room, and from there carried directly to the beaters on trucks. As the workman must lift the pulp from the bottom to the top on a shovel, their depth is limited by his height, or about 5 to 6 feet.

The walls are exposed to the pressure of a body of liquid as large as the drainers will hold, and must be of sufficient thickness. Any wall less than one and a half brick, or about 14 to 15 inches strong, would be likely to spring out and crack under the pressure of a filled drainer. To protect the top of these walls against the feet of the workmen they must be covered with a framework of heavy planks, a trifle wider than themselves.

Cisterns of this kind are sometimes preferred, because the pulp can be taken to the beaters without the aid of a hoister, but it must not be forgotten that the work of the elevator is not entirely saved, but done by men.

In large mills, where hoisters are considered as indispensable as any other part of the machinery, the second plan is more frequently adopted.

The drainers are then not restricted in height, and can be located on any part of the floor below the engines, where room enough can be obtained to run a truck alongside of them, for the purpose of carrying away the pulp. Their walls must be stronger as they are higher, and should never be less than two bricks, or 18 to 20 inches thick.

In one of the largest and best constructed mills in America there is one such drainer, standing independently by itself, under every engine. Iron girders rest on the strong brick walls of these drainers and carry the engines.

The doors must be large enough for a man to pass in and out, their cast-iron or wooden frames are walled in, and they are fastened outside of the drainer-walls in a manner convenient for opening and closing them.

To be convenient for emptying, the lower door-sill should be about as high above the floor as the tops of the truck wagon which is to receive the pulp.

42. Construction of Drainers.—The foundations of these drainers, and especially of their side-walls, must be solid and uniform, as the walls must crack if they settle more in one place than in another.

Only sound brick and good fresh cement are suitable to be used for them, and men skilled in cement-work must be employed.

Every brick is to be saturated well with water before being laid in the cement-mortar.

Cement will only harden with abundance of water; in fact, too much cannot be used.

After the walls are finished, they are to be coated with cement by a good plasterer, who will also take care to use water in profusion, and as soon as the cement is hard, the drainers may be used.

The false bottom consists usually of boards or planks, which are full of holes, covered with wire-cloth or bagging, and supported by blocks or rows of bricks. Both wire-cloth and bagging are on hand in every mill, the first from the machine, and the latter as baling material, and may be used according to the supply of one or the other.

Wire-cloth is preferable because it lasts longer, but bagging has the advantage of being bleached white, ready for pulp by the time it is worn out.

The wire-cloth or bagging is protected against the feet and tools of the men, who take out the pulp, by loose boards laid over them in such a way that they leave space enough between them for the escape of the liquid.

Perforated tiles or bricks are also in use for this purpose, but we understand that they sometimes give trouble by breaking, though it might be supposed that their manufacture could be perfected so as to overcome this difficulty.

The outlet, which is provided for the escape of the liquid from the drainers, must be closed by a stop-cock, if it is not desired that the bleach-solution should run off as soon as it reaches the bottom.

43. Waste Bleach-Liquor.—If the waste liquor is to be pumped into an upper receiver, to be transformed again into fresh solution, or to be made use of for preliminary bleaching, a stop-cock is not required.

The solution is in that case conducted through a lead pipe into a reservoir below the drainers, and it may here be suggested that in rag-mills where the amount of bleaching powders is comparatively small, the expense caused by receivers above and below, pump, pipes, power, and repairs, may often be a full offset to all the benefit derived from this source. It is also to be remembered that the bleaching chlorine or hypochlorous acid of such solutions is not only gradually disappearing and replaced by the carbonic acid of the air, but that these changes are greatly assisted by all the manipulations which the liquids are made to undergo.

It is certainly better to use the powders with economy, but always fresh, than to bleach with an excess, in the expectation to recover it from the waste liquor.

It is, however, in all cases advisable to gather the fluids escaping from the drainers into a cistern, where the fibres, which may have escaped with them, can be deposited.

The floor of the drainer-room is exposed to droppings of water from many sources, and has to be frequently washed. It should have a smooth pavement, slanting towards a drain, through which all these waters can run off.

44. Sour Bleaching is the process of bleaching which is carried on partly or altogether in drainers. High and capacious drainers, holding 5000 to 10,000 pounds of pulp, are best suited for it.

The name is derived from the use of acid, which acts exactly as it does in the engine, in connection with the solution of powders.

After the drainer has been filled with half-stuff, the bleach solution, previously prepared in a reservoir above it, is admitted on top.

The half-stuff, in losing the water, shrinks into a smaller volume away from the sides, and any liquid poured on it in that condition would run down along the sides without penetrating it. The drainer must therefore be prepared for the bleaching operation by a workman, who enters and packs the half-stuff tight all around.

Enough bleach solution must be used to saturate the whole mass, but no more; and after a short time largely diluted vitriol is emptied on it from another reservoir.

The quantity of each solution which is required for a certain amount of stuff is soon ascertained by experience.

Some paper-makers reverse the process by adding the acid first and the bleach solution second; and others mix the chlorine preparation with the pulp in the engine before emptying.

In one of the largest and best managed mills of this country the bleach solution is divided into two parts: the first smaller one is mixed with the stuff in the engine and emptied with it, the acid is run into the drainer after it has been filled, and the second larger part of the bleach solution is added last from a reservoir.

This method is modified in all imaginable ways by bleaching partly in the engine and partly in the drainer, and has the advantage that it saves the time otherwise used by the washing engines for bleaching. If it is done entirely in the drainers, the contact of the solutions with the iron of the engine is avoided.

It has the disadvantage that the progress of the operation cannot be watched, and that, even with the greatest care, some portions of the pulp do not receive their due share of liquor, and are taken from the drainers imperfectly bleached.

45. Bleaching Engines.—The fine paper manufactured in this country is probably all bleached in the washing engines; separate bleaching engines are not, to our knowledge, used anywhere in the United States.

The only ground on which special bleaching engines can be recommended is, that they are constructed especially for the purpose, without knives, and of materials which cannot be corroded or destroyed by acids, such as lead or stone.

Such bleachers must be situated below the washers, connected with them by spouts, and above the drainers into which they are emptied.

The building, gearings, spouting, pipes, &c., are thus made more complicated; and it is very doubtful if the benefits derived are proportionate to the increased cost.

The damage done to the knives of the washing engines by the chlorine or acids is practically very trifling, and the iron, which might be introduced into the paper from this source, is probably less than the inevitable quantities contained in nearly all waters.

(d) *Bleaching with Gas.*

46. Preparation of the Pulp.—The same drainers in which the process of sour bleaching is carried on, are suitable for the reception of washed half-stuff which is to be bleached with chlorine gas.

It is important that the pulp should be pretty dry, as otherwise the water surrounding the fibres absorbs a part of the gas and withholds it from the intended action on the stuff. Though it must be dry enough not to yield any water if pressed in the hand, it should yet be moist.

The half-stuff must remain a long time in the drainers to reach that state, and a large number of the latter is necessary.

To avoid this and to save a large amount of capital in the form of prepared rags from being always locked up in the drainers, several methods have come into use by which the half-stuff is dried mechanically.

The first one was to force the water out of the half-stuff in a strong press, and to tear afterwards the solid body thus formed into shreds by means of pickers or devils. This required much labor, and the half-stuff, after all, did not possess that sponginess which makes it easy for the gas to penetrate it.

Centrifugal drainers, similar to those used as cloth-wringers, are also employed for this purpose. Fig. 43 represents one of them, made by Messrs. Rice, Barton & Fales, Worcester, Mass.

The upright shaft is the centre of a cylinder with solid bottom, and sides formed of strong wire. This cylinder is filled with wet half-stuff, and turned 1000 to 1500 times per minute by the belt. The centrifugal power created by that speed throws the pulp with great force against the wire sides; the water escapes through the openings, while the fibres are held in and form a thin, spongy band all around. A few minutes are sufficient for such an operation, the dry pulp is removed by hand, and a fresh supply of wet pulp packed in.

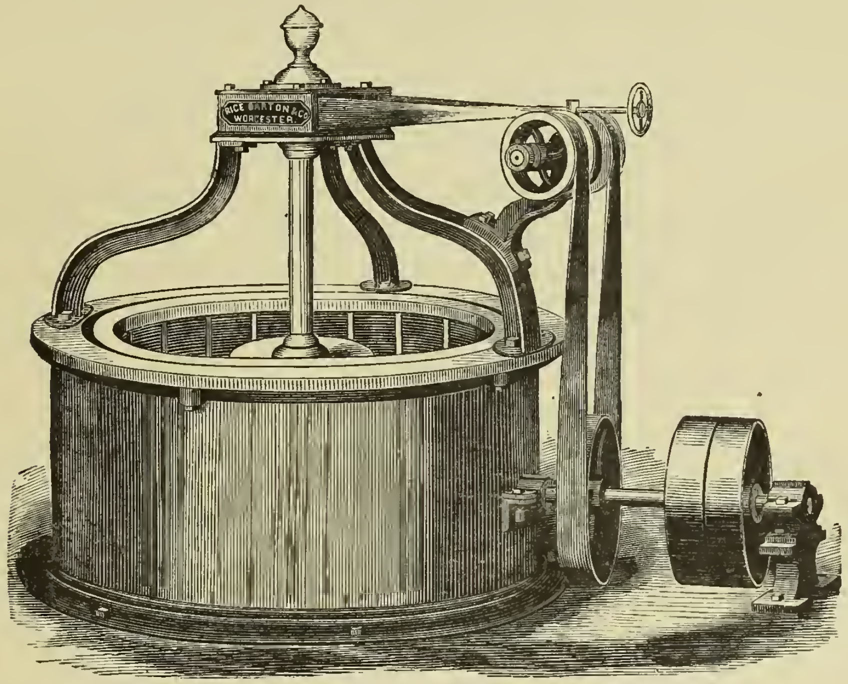
This machine furnishes the half-stuff in as good a condition as can be desired, but it works by stops and starts, and requires much labor.

The best continuously running apparatus for this purpose is the making cylinder and first press of a cylinder paper-machine, called a wet machine, and used extensively for straw and wood pulp.

The washing engines are emptied into a stuff-chest with agitator, from which the cylinder is supplied. The half-stuff forms a web, as on a paper-machine, and is taken off in rolls.

The gray half-stuff dried by one of these methods is piled into chambers of brick and cement, similar to the drainers described before, but with an arch of the

Fig. 43.



same material covering the top. The chlorine would not be able to penetrate through it if the stuff were allowed to form a solid pile; it is therefore laid on wooden shelves made of scantling without the use of metal, as nails or otherwise.

47. Chlorine Gas and its Preparation.—Chlorine is a yellow-greenish gas, of very strong, suffocating smell; it affects the throat and lungs violently, and if inhaled in large quantities may cause sudden death. Its specific gravity is 2.4, or it is nearly two and one-half times as heavy as our atmospheric air.

It is easily produced from a mixture of peroxide of manganese with hydrochloric acid under the influence of heat. Earthen retorts, surrounded by an earthen or iron mantle or jacket, are used for it. The hollow space created by this jacket is filled with water, into which steam is introduced in sufficient quantity to heat it, without allowing it to reach the boiling-point. If the temperature should rise too high, the liquid contents of the retort would be bodily carried to the pulp in the form of vapor.

Manganese is a mineral which contains variable quantities of peroxide of manganese, according to the different mines from which it comes—sometimes as large

a proportion as 90 per cent. The retort must be opened to introduce this substance, but the hydrochloric acid can be poured in, as it is required, through an N-shaped lead pipe, which is fastened in the cover. Some of the acid always remains in the bend of the pipe and prevents the escape of gas.

The oxygen of the peroxide unites with the hydrogen of the hydrochloric acid and forms water; one-half of the liberated chlorine joins the manganese, and the other half escapes through the lead pipe to the bleaching chamber, which it enters through the centre of the covering-arch. The equation for this chemical transformation is as follows:

$$\underset{\text{Peroxide of manganese.}}{MnO_2} + \underset{\text{Hydrochloric acid.}}{2HCl} = \underset{\text{Chloride of manganese.}}{MnCl} + \underset{\text{Water.}}{2HO} + \underset{\text{Chlorine.}}{Cl}$$

The gas often, especially if heated too much, carries some hydrochloric acid along to the half-stuff, giving it a yellow appearance; but it can be easily prevented from doing so if forced to pass, on its way to the chamber, through a pipe or pot filled with manganese. The hydrochloric acid joins the manganese, creates again free chlorine, and is thus not only made harmless, but even useful. Three to five parts of acid are used to one of manganese; and it is always safe to take an excess of the latter, as the chloride of manganese is soluble in water and can be washed out, while the remaining mineral may be mixed with a new portion of manganese, and thus thoroughly exhausted.

In some localities it may be cheaper to use sulphuric acid and common salt in place of hydrochloric acid, and then these take the place of it in the retort.

Common salt or chloride of sodium is a combination of chlorine and sodium, which, with sulphuric acid, forms sulphate of soda and hydrochloric acid, according to the following equation:

$$\underset{\text{Sulphuric acid.}}{SO_3HO} + \underset{\text{Chloride of sodium.}}{NaCl} = \underset{\text{Sulphate of soda.}}{NaOSO_3} + \underset{\text{Hydrochloric acid.}}{HCl}$$

The hydrochloric acid being thus produced, the rest of the process is the same as before described.

The quantity of chlorine and chemicals needed varies for rags of different quality and color, and must be found by experience.

48. Process of Bleaching with Gas.—The gas, having entered on top, soon descends by its weight through the stuff to the bottom of the drainer, bleaching it according to the same laws which govern the action of liquid solution. There is always and must be enough moisture or water left in the rags to furnish the bleaching oxygen, without which the chlorine has no effect on them.

The process can be watched by placing a small lot of stuff near an opening in the door, whence it can be withdrawn and examined. When it is found to be white the door is removed, but the smell is so offensive that it has to remain for some time before anybody can venture to approach it. Bleaching chambers have, in some in-

stances, been connected with the chimneys of steam-boilers and with ventilators, for the purpose of carrying off the excess of gas, but only with partial success.

Where chlorine gas is made, its escape through breaking or leaking retorts, pipes, or chambers, cannot be entirely avoided, and is offensive enough to try anybody's lungs and patience. Even if the bleaching is done at a distance from the mill, it is bad for the workmen to be obliged to submit to the ordeal of removing the pulp from the chambers yet partly filled with gas.

Chlorine gas acts very violently; it must have destroyed some of the finer fibres before the coarsest ones are white, and thus causes considerable loss.

The use of gas should give way to that of solution wherever possible; the former should be used only for the coarsest fibres, and then only in insufficient quantities, and the process finished with liquor in the engine.

We know of only one mill in the United States where chlorine is used in the form of gas.

SECTION IV.

(*a*) Mixing, (*b*) Washing and Beating, (*c*) Sizing, (*d*) Coloring, (*e*) Patent Engines, (*f*) Stuff-chests and Stuff-pumps.

(a) *Mixing.*

49. General Remarks.—It is in mixing the pulp from different fibres, wherein the paper-maker displays more than in any other operation his knowledge and judgment. He must understand the nature of the raw materials in order to blend their different qualities in proportions, which make up a paper, answering in every respect the purpose for which it is intended.

It is not supposed that any paper-mill, however extensive, should keep a stock of all kinds of rags and other fibres on hand, so that it could make any grade of paper which might be asked for. It is, on the contrary, advisable that each establishment should confine itself to one class of papers, and only buy such rags as are suitable for that class. If there is an advantage in buying and sorting mixed rags, those portions which are either too fine or too coarse for the use of the mill should be sold to other manufacturers.

Though the manufacture of one class of paper may be strictly adhered to, all endeavors to use for it lower grades of rags or other available stock deserve to be encouraged.

50. Rules and Example.—As a general rule the best rags are reserved for the finest or highest-priced papers, and so on down.

The relative prices of different kinds of rags can alone decide whether it pays to

work cheap stock into higher grades of paper; for it must be remembered that such rags have to undergo a good many more operations, and therefore lose a larger proportion of their weight than better ones.

Coarse fibres may, by energetic boiling and bleaching, be transformed into white paper, but this suddenly acquired splendor will not prove as permanent as that which was inherent in the raw material.

The tendency of the paper, to turn dark or yellow in the course of time, will be proportionate to the chemical treatment and the transformations to which the fibres have been subjected.

For writing purposes, a strong, stiff, crackling sheet is desirable; while printers' types give a better impression on soft paper. Strong fibres, such as linen not much worn, usually compose the larger part of the former; while well-worn cotton rags are suitable for the latter.

In thin papers the length and strength of the fibres have to make up for their scarcity, and the strongest of flax and hemp rags, or even ropes, must be used. The thicker or heavier a paper is to be, the more of weak material may enter into its composition.

The work of the paper-machine must also be considered in mixing the pulp, so that no difficulties will be experienced. If the pulp for a heavy sheet would be made up of long and tough fibres only, it would not lose enough water on the wire, but enter the presses in a wet state, and become crushed.

All the paper in this book is composed of one-third No. 2 Italian linen rags and two-thirds domestic cotton rags of all colors; the thin paper of the plates has only been beaten a longer time in the engine and contains no clay. Some delaines were mixed with the cotton rags, but the wool as well as the colors disappeared under the influence of caustic lime in the rotary. They were bleached in the washing engine, with about 10 pounds of bleaching powders per 100 pounds of paper, a solution being made fresh for every engine. One-quarter of a gallon of vitriol was added to every 500 pound engine, and the pulp emptied into open brick drainers.

It is the paper-maker's aim to make the best possible paper with the least expense out of the raw material. Judgment and experience alone can teach how to do this; the ever-changing prices and demands of the markets, and the difference of the raw materials in various countries and even localities, prevent the establishment of any rules or prescriptions.

(b) *Washing and Beating.*

51. Washing, and Testing for Chlorine.—No matter how the rags have been bleached, some chlorine, hydrochloric acid, chloride of calcium, and other products of the bleaching process, are always adhering to them, which, if left in the paper, not only injure its durability by turning it yellow and brittle in the course of time, but also prevent perfect sizing and coloring.

If considerable quantities of chlorine have been left in the pulp, they will act on the fibres until they have destroyed the paper. If the quantity of chlorine is very small, it will evaporate with the water on the drying cylinders, dissolve some of their iron, and the iron-salts thus formed will impregnate the dryer felts, which deliver them again to the paper.

Messrs. Fordos & Gelis have found, by numerous experiments, that pulp did not contain any iron when taken from the beaters, but a considerable quantity after it had passed over the machine.

These iron-salts in the finished paper are originally of a very low state of oxidation and colorless, but gradually take up oxygen and moisture from the air, and give to the paper the well-known yellow, rust-like color.

After the beater has been loaded with its due portion of pulp and water, our efforts must be first directed to the expulsion of the chlorine. The beaters are for this purpose provided with one or, better, two such revolving washers as we have described before, and with a good stream of clear water.

The roll must be kept raised while the wash-process is going on, to prevent cutting of the fibres, a portion of which might, if reduced too much, escape through the washing cylinders.

The thorough elimination of chlorine in all its combinations is too important a matter, to be left entirely to the judgment of the engineer or to chance.

Blue litmus-paper in contact with any acid liquid turns red, and can be used with advantage to test the pulp. As long as the blue litmus-color of a small slip of paper, immersed for a moment in the engine, is thereby turned red, the washing is to be continued.

This test is so simple that it can be applied by anybody. The foreman should have some of the litmus-paper on hand at all times.

There is, however, a more sensitive method by which the presence of chlorine can be established with certainty. It is constantly and successfully in use in several of the best New England mills, and is based on the characteristic color which iodine produces in contact with starch.

Iodine is an element of the same class as chlorine, and its combination with potassium—the iodide of potassium—can be purchased at any drug store. We dissolve it, for our use, in pure water and with enough good white starch to make a milky liquid. Proteaux recommends a mixture of

Iodide of potassium, ...	1 part.
Starch, ...	2 parts.
Water, ...	3 parts.

This solution of starch and iodide of potassium is kept in a small bottle for use by the foreman or engineer. To test the contents of an engine, a handful of the pulp is taken out, pressed so, that the excess of liquid runs off, while leaving the pulp yet wet, when a few drops of our solution are poured on it.

If any blue, purple or violet color, however faint it may be, makes its appearance, the chlorine or chlorine acids have not entirely departed. Chlorine has a stronger affinity for potassium than iodine, and leaves its companions to join the potassium as chloride of potassium, thereby setting the iodine free, which, finding itself in the presence of the starch, shows the characteristic blue color.

52. Antichlorine.—Many chemicals, especially hyposulphite of soda, have been proposed as so-called "antichlorine;" they all consist of salts which take up the chlorine or hydrochloric acid in the pulp, and form neutral combinations with them. They are recommended on the theory that the chlorine is thus made harmless, and it is true that they must prove a great improvement, where none or only imperfect washing has been practiced.

The presence of chlorine is especially obnoxious in the manufacture of some colored papers. In some mills antichlorine is therefore added to the pulp before washing, in order to neutralize any free chlorine which might possibly remain after the operation of washing has been finished.

It is generally admitted that the presence in the pulp of the salts formed by the antichlorine is not desirable, and that they should be washed out. Thorough washing is thus on all hands considered indispensable, and, if done with the necessary care and precaution, the money spent for antichlorine may be saved.

53. Beating.—The word "beating" expresses well the operation which follows the washing; it indicates that here as well as in the washing-engine the rags are not to be cut, but that the fibres must be drawn out to full length by the action of the knives and the friction among the rags themselves.

If this theory should have to be carried out literally for all kinds of stock and paper, most paper-mills would require twice or three times as many beaters as they have now.

The price of a few grades only, such as bank-note, justifies so expensive a process, but however limited may be the power and the number of beaters, it must be the manufacturer's aim to work up to the principle as far as his mill will permit.

As soon as the washing cylinders are raised and the wash-water stopped, the engineer lowers the roll sufficiently to begin the operation. As the disintegration proceeds and the rags disappear, the space between the knives must be further diminished. The slower this is done the longer will be the fibres.

Slow beating and blunt knives make long pulp; quick work and sharp knives short pulp.

While a beater may be run off in from three to five hours for thick paper, twenty-four and more hours are required for the thinnest sheets.

To examine the pulp, a small portion of it is dissolved in a basin with a large quantity of water, and slowly poured out so that it flows over the rim as a very thin sheet. If any little knots appear in it, or if the pulp looks cloudy instead of being uniformly divided, it must be brushed or drawn out more. The engineer lowers the roll for this purpose so far, that its edges approach those of the plate as much as pos-

sible without actually touching them, and turns the pulp with the paddle. The rags are liable to lodge on the bottom or in corners, and it is the engineer's duty to stir up the pulp frequently, especially in those places.

Experienced paper-makers often express their opinion of the importance of the beaters and engineers in charge of them by saying that the paper is made in the beating engine.

Though this will apply to every one of the operations which rags have to undergo, it indicates correctly the value of a good engineer.

54. Self-Actors.—An attempt has been made to make the mills to some extent independent of the skill of these men by means of self-actors.

The self-actor is a mechanical contrivance driven by a cord, which lowers the roll automatically. It replaces the hand-wheel and screw, by which the engineer raises and lowers the lighter, and occupies its place at the engine. The upright rod has a strong pin through it, resting on a steel ring, of which the rod is the centre. The surface of this ring is shaped so that the pin, while passing once around the circle, descends gradually about $\frac{1}{2}$ inch. This descent is not uniform, but curved in the same proportion to the whole time or circle, as a skilful engineer would lower the roll while working off one beater.

The pin and rod have no turning movement, but the steel ring which is fastened on a worm-wheel, makes a revolution in from four to eight hours.

The shaft, which carries the worm, is parallel and corresponds with a reduced extension of the roll-shaft, and both are provided with a set of small cord-pulleys. The speed of the self-actor can thus be changed by the use of different pulleys and the time of an operation varied to suit the different kinds of rags; but the descent of the roll bears to the time always the same proportion, as the curve of the ring remains the same.

It may answer for the manufacture of a certain kind of paper from a certain stock.

But if the quality or weight of the paper to be made, or the raw material, or even the treatment of the rags previous to beating is often changed, the hand of a skilful engineer is alone able to conduct the operation so as to suit all circumstances. This is probably the reason why self-actors have not become very popular in paper-mills.

55. Plates and General Construction of Beaters.—All the bed-plates described in the section on washers are likewise used for beaters, but the elbow-plates seem to be generally the favorites. The cast-steel ones, $\frac{1}{16}$ to $\frac{1}{8}$ inch thick, filled in with wood, which remain sharp all the time, deserve here the preference.

Only in a few of the fine New England mills are brass bed-plates substituted for steel ones. They have mostly the form of solid elbow-plates, and certainly cannot fail to furnish a long fibre, as they are too soft to cut it. It is true that they are more expensive than steel plates, but if they furnish tougher paper, or enable us to

use weaker rags in place of stronger ones, they will prove the more economical of the two.

The principles, explained for the washing engine in the foregoing paragraph, govern the construction of the beaters, with only slight modifications.

The rags, furnished to the beating engine, are already prepared to some extent, and therefore do not require as violent a treatment as in the washers.

The rolls of the beaters for this reason carry usually more fly-bars, and make 25 to 50 revolutions more per minute than the washers.

The vat of the beating engine may, for the sake of economy, be made deeper than that of the washer, but a moderate height is preferable for engines of all kinds.

56. Power consumed by Engines.—The power consumed by an engine varies with the nature of the rags, the manner and time in which they are treated, and with the sharpness of the knives.

It is impossible to give any exact data for it, but we have tried to ascertain through exchange of views with experienced manufacturers, what may be considered a fair estimate.

The majority of all the engines in this country have a capacity of from 4 to 600 pounds, and require, with medium qualities of mixed rags and ordinary treatment, an average of from 10 to 15 horse-power.

(c) *Sizing.*

57. Comparison between Surface Sizing and Sizing in the Engine.—The large bulk of all white paper is used for writing and printing purposes, and must be prepared to suit either one or the other.

Printers' ink is an oily, little-fluent substance, which does not spread beyond the limits given by the type on any common paper. Writing ink, being more diluted and watery, allows itself to be absorbed from beyond the space, assigned to it by the pen, on a thirsty sheet. Unsized linen or cotton paper is full of pores, or little cavities and channels, into which the writing ink flows, and spreads itself until it is all absorbed.

Printing paper therefore does not require any sizing, but it is necessary to fill the pores or cover the web of writing paper with some substance, which will prevent it from swallowing up the writing fluid.

Hand-made paper is simply dipped into a solution of gelatine or animal size; the surplus is removed by pressing it between felts, and the sheets are hung up to dry slowly by evaporation.

The gelatine, when dry, forms an impermeable coating on both sides of the paper, which separates the ink from the absorbing pores.

Machine-made paper is treated in a similar way, which we shall describe after having first shown how the paper is made.

Paper, made on the machine or by hand, used to be treated alike after it had been sized in this way, and required a great deal of labor before the improved system, described in Section VI, had been gradually developed.

It was therefore natural that the paper-makers should have been anxious to find a process by which the paper could be produced sized, in the same time, and with no more labor than when unsized.

Engine sizing or sizing in the pulp is the result of these attempts.

Surface-sized paper is covered with smooth uniform coats, but its pores are imperfectly filled; while the fibres are each separately surrounded, the pores filled, and the whole mass impregnated with the sizing material, if the paper has been sized in the engine.

If surface-sized paper is scratched and the coating removed, it will not hold ink any longer in such places, but acts like printing paper, while paper sized in the pulp, can be written upon as long as there is any of it left.

Surface-sized paper is smooth, and offers no obstacle to steel pens or drawing utensils, while paper sized in the pulp, even if well calendered, is rougher, and not so agreeable to write upon.

The fibres of unsized paper interpose themselves without obstacle, so as to form a tough, closely-felted sheet, but the fibres of engine-sized pulp are surrounded with the size, and lose thereby much of the soft pliability which is necessary for a perfect web.

Unsized paper is therefore always found stronger, though not so stiff, as engine-sized paper, made of the same material and in the same way.

Mr. G. Planche states that, according to experiments made, the tenacity of unsized paper is 25 per cent. higher than of the same sheet sized in the engine, or the former will carry 25 per cent. more weight before it breaks than the latter. Narrow strips of equal size are cut from the papers which are to be thus tested; they are fastened at one end and the weights attached to the other.

The number of pounds which are required to break the samples shows their comparative tenacity.

Surface-sized papers receive an addition to this strength from the two coats of size, which is quite considerable.

All these advantages are appreciated by the public, and surface- or animal-sized paper is nearly altogether used for letters and the better classes of blank books in England as well as in the United States. Though this method of sizing causes additional expense, the manufacturer is compensated by higher prices, and the greater strength, which enable him to use a much larger proportion of cotton rags than paper sized in the pulp would admit.

Very often both systems are united by sizing the pulp first and the web afterwards.

58. Sizing in the Engine.—The prescriptions for sizing in the engine are as numerous as the patent medicines which are infallible cures for nearly every disease, and equally effective. The proportions which answer in one case cannot suit in another, where the raw materials, the paper to be made, and the machinery used, are different.

Nothing can disclose the secret of making a well-sized paper but practical experience combined with a thorough knowledge of the chemical process, through which alone it can be produced.

The resinous size, generally used at the present time, is obtained by adding a solution of sulphate of alumina or alum to a soap of resin dissolved in soda.

Alumina (clay) has a very strong affinity for vegetable substances, and combines with resin mechanically, but with a strength equal to a chemical union, forming a resinous alumina.

When solutions of resin in soda and of sulphate of alumina are brought together, the sulphuric acid forms with the soda, sulphate of soda, and the resin and alumina are deposited as resinous alumina.

59. Preparation of Vegetable Size.—The soda or oxide of sodium in soda-ash or in crystals of soda is united with carbonic acid to carbonate of soda (NaO,CO_2).

The presence of carbonic acid is objectionable, as it escapes in bubbles while the solution of resin is made, or as foam in the engine.

The soap-makers use caustic soda (NaO), free from carbonic acid, for the solution of resin, and it was naturally supposed, that it would answer better for size than the carbonates.

Gabriel Planche, in his valuable work on *Paper-making*, recommends the use of caustic soda instead of the carbonates. The soda is for this purpose boiled with caustic (fresh-burnt) lime; the mixture is allowed to settle, and the clear now caustic liquid is used for the solution of resin.

This has frequently been tried by experienced paper-makers, but it has generally been found that the size made with caustic soda was not as efficient as that made with ordinary soda-ash or crystallized soda.

We are unable to give a positive explanation of this fact, but, as the resin must be precipitated again in the engine, it is perhaps not desirable to dissolve it, or destroy its character as thoroughly as if washing soap were to be made. The solution of caustic soda may contain a portion of the lime which has been used to causticize it, and also some of its impurities, and the presence of these substances may prevent the formation of a good sizing soap.

The solution of resin is mostly made in an ordinary wooden tub furnished with a steam-pipe, but a copper or iron caldron, surrounded by an iron steam-mantle or jacket, would be preferable. With this latter arrangement the steam will fill the jacket instead of entering into the solution and constantly diluting it.

The soap could be removed clean and clear from the metal, while it sticks very closely to wood.

A tub or caldron, of about 4 feet diameter at the top and 3 feet high, with narrower rounded bottom, holding about 250 gallons, is of convenient size for dissolving two barrels of resin.

The soda and a certain quantity of water are mixed in this tub; steam is ad-

mitted, and as soon as the liquid boils, the finely-powdered resin is gradually thrown in. The boiling heat is kept up, and the whole mass is constantly stirred with a paddle until all the resin is dissolved.

If water has not been very sparingly used, the resin soap, a pasty, syrup-like mass, settles on the bottom, and the remaining solution of soda floats on top. The alkaline liquid can easily be removed, but the impurities of both the resin and soda become mixed with the soap on the bottom of the tub.

It has been found by some of our experienced paper-makers, that the most effective size is obtained, if the resin is dissolved in a solution of soda-ash of such concentration, that its specific gravity is greater than that of the resin soap. In that case the soda solution remains on the bottom, while the resin soap floats on it, and the soap never boils over while it is being prepared, as it does with diluted solutions.

After the resin and the soda solution have been boiled and stirred for about two hours, the resin soap can be taken out in a perfectly clean condition, as the surplus solution and all the impurities remain on the bottom.

The resin is better dissolved if it floats in the solution than if it falls to the bottom.

The concentration of the solution is not produced by the use of more soda, but by the reduction of the water to the smallest possible quantity with which the resin can be dissolved. If, for instance, one pound of soda-ash for every four of resin is the established proportion, 125 pounds must be taken for two barrels or 500 pounds of resin. The minimum quantity of water which is required, can easily be found by a few trials.

The addition of sugar of lead to the soda solution is frequently recommended and found useful, probably because its heavy specific gravity increases that of the solution. But as the desired gravity can be produced with soda-ash alone, it is unnecessary to resort to other means.

If it is found, after removing the soap, that a large quantity of soda solution is left, more resin or less solution may be used the next time.

If the resin, after it has been boiled as long as is usual, is not well dissolved, the proportion of soda must be increased.

The quantity of soda (oxide of sodium, NaO) contained in commercial soda-ash, varies from 47 to 57 per cent., and 4 pounds of that of 57 per cent. are equal in effect to 5 pounds of 47 per cent.

The purest soda-ash, no matter of what percentage, is to be selected.

Some paper-makers use 3, some 4, and others 5 pounds of resin to 1 pound of soda-ash, and as a surplus of soda cannot do any harm, they may all be successful.

Crystals of soda contain a large quantity of water, and only about 22 per cent. of soda (NaO); they are therefore a very expensive material. They will hardly dissolve twice their weight of resin, but are nevertheless sometimes preferred to soda-ash, because they are purer.

D'Arcet recommends—

Powdered Resin, ...	4.80	parts.
Crystals of Soda, ...	2.22	"
Water, ...	100.	"

Time, 2 to 3 hours.

A few experiments will give the proportions of soda, resin, and water necessary in every case, better than any prescription.

We weigh the resin contained in two barrels; pulverize it, and then take for every 4 pounds of resin 1 pound of best soda-ash; dissolve it in our tub or caldron with a few (say 10) buckets of water; turn steam on, and throw in the powdered resin with a shovel as soon as the liquid is boiling.

The liquid is stirred with a paddle while the resin is added, and if it is found that the water is absorbed before all the resin is dissolved, we have to pour in more; but if the soda solution, on cooling, comes to the top instead of remaining on the bottom, we must reduce the quantity of water next time.

It is always safe to use a surplus of soda-ash.

Mr. Adam Ramage, writing under the name of "Papyrus," recommends in No. 20 of the *Paper-Trade Reporter* the following method of testing whether the resin is thoroughly dissolved:

"Take out a little of the solution by allowing the stirring-paddle to drip into a basin half full of milkwarm or cold water; dash this up well with the hand. [The pulp being mixed with cold water in the engine, none but cold water should be used for this test.—The Author.] If it dissolves freely in the water, and if, after shaking the size off the hand, there are no fine particles of resin adhering to the hairs on the back of the hand, the size is made; if, however, although it may seemingly dissolve in the water, there is a dry white deposit on the hairs, it is not boiled enough; so boil for a few minutes longer and test again. Continue this until it will stand this test. This, I confess, is quite a homely test, but it is a sure one. Just as certain as there is undissolved resin present, it will adhere to the hair on the back of the hands. Of course you must be careful to keep the hand and the basin clean and entirely free from acid or alkali."

To this we may add, that more soda-ash must be mixed in if, after prolonged boiling, a thorough solution is not obtained.

The time prescribed for such an operation varies from fifteen minutes to five hours; and it makes little difference how much it really takes, provided that the soap be well made. If the steam is introduced directly into the mixture, it dilutes it by condensing, and for this reason it may be preferable to shorten the time as much as possible.

If the resin is not well dissolved, small particles of it appear as yellow spots in the paper. The better the resin has been powdered, the easier will it dissolve; and it would pay for large factories to use a little mill, consisting of a vertical revolving stone running on a stone or iron platform, for grinding it.

In some mills, where the soap is made with concentrated solution, as described, it is so perfect that it can be passed through a No. 60 wire-cloth and used directly in the engine.

60. Use of Starch.—In many mills it is, however, first mixed with starch, and for this purpose must be more diluted. This is done in a tub lined with sheet zinc, and provided with a steam-pipe.

The starch is dissolved in this tub by means of hot water, and a measured quantity of resin soap is added to the solution, while the liquid is constantly stirred to prevent the formation of lumps.

It is necessary that we should know exactly how much resin is contained in a gallon of the soap and how much in the dilution, because the number of gallons or buckets used for an engine of pulp is to be regulated accordingly.

The solution must be diluted enough to be passed through a No. 60 wire-cloth, which retains all the impurities.

From 3 to 6 pounds of resin, or a corresponding number of gallons of the diluted soap, are usually sufficient to size 100 pounds of medium qualities of paper of ordinary weight. For very thin paper or short, weak fibres, the quantity may have to be increased; while less of it answers for heavy paper, made of strong pulp.

Either two large tubs, in which the size can be mixed and diluted, or one tub and a receiver, into which the former one can be drawn off, should be on hand, so that one can be used while the solution is prepared in the other. They should stand high enough, to permit the size to be drawn off through stop-cocks at the bottom.

Starch is not necessary, but improves the size. It envelops the resin, retards its precipitation through alum, and thereby makes the sizing more uniform; being perfectly white, it covers to some extent the more or less dark color of the resin and even the faults of a deficient solution.

About 1 pound of starch for every pound of resin is the average quantity used in most mills; but it can be considerably increased without injury, if desired.

61. Proportions Used in Different Mills.—The author used to make a very thin pulp-sized letter-paper with a resin size, which was prepared in a caldron heated by steam in an outside jacket.

150 pounds of crystallized soda were dissolved in about 90 quarts of water, and 250 pounds of powdered resin added to the boiling liquid. It was kept stirred up with a paddle, and the whole operation occupied from four to six hours.

A portion of the soap thus obtained was diluted with warm water, and mixed with a similar quantity of dissolved starch, producing a very fluid yellow liquid, which could easily be filtered through a No. 60 wire-cloth into the beaters.

At a mill in this country where writing paper is made as a specialty, size is prepared in the following manner:

In a wooden tub, furnished with a steam-pipe, are dissolved 125 pounds of soda-ash with 10 buckets (30 to 35 gallons) of water, and set to boiling by the direct introduction of steam. The liquid (which tests about 30 degrees Baumé at boiling

heat) is constantly stirred, and two barrels or about 500 pounds of powdered resin are added, until after about two hours the soap is finished or the resin "cut."

If too much water has not been used, the soap floats on the solution, and after having rested about half an hour, but yet hot, is passed through a No. 60 wire-cloth into several barrels, which serve as reservoirs, while the surplus soda solution and the impurities remain on the bottom.

High pressure steam is used for boiling in this way, because less of it is required, and the solution not so much diluted as by steam of lower pressure.

Five pounds of porous alum for every 100 pounds of paper are dissolved in water, and poured through a No. 60 wire-cloth into the engine. After the alum has had time to become thoroughly mixed up, 1½ buckets of the resin soap, containing about 18 pounds of resin, are likewise added to the 400 pounds of pulp in the engine.

About 6 pounds of starch, previously dissolved in about ten times their volume of water, are also strained through No. 60 wire-cloth into the engine, independently of the resin, but at about the same time.

The two methods just described are very different, and yet both furnish good results.

We consider the solution of resin in concentrated solution of soda-ash preferable, for the reasons before stated, but would recommend the use of a jacket instead of the direct introduction of steam.

The object of the starch, to retard the precipitation of the resin by enveloping it with its own slimy mass, can hardly be accomplished if the soap and starch are separately added to the pulp, and it seems therefore advisable to unite them in one common solution. Care must, however, be taken in either case to dissolve the starch in a sufficient quantity of water, as it will otherwise congeal into flakes or spots in the pulp.

62. Addition of Glue and Other Substances.—Many paper-makers have tried to give to engine-sized paper the qualities of that sized in the sheet, by adding glue dissolved in water to resin soap, or by pouring it separately into the engine just before emptying the latter. It is possible that a stiffer paper is thereby produced, but the two methods—the one of sizing the fibre and the other of coating the paper—are so different, that the possibility of either one replacing the other is excluded, no matter what materials are used.

Numerous other substances have been recommended as additions for the improvement of the resin soap, and we shall mention two of them, because they are used by experienced and successful paper-makers.

The paper of the plates in this book is sized with a resin soap, prepared according to the latter of the two methods described in Art. 61, and containing also 12 pounds of "*gum tragacanth*" for every 500 pounds of resin.

This gum tragacanth is the effusion of a Persian plant; it does not dissolve as freely, and gives a thicker, more gelatine-like mass than most other gums. It is dissolved in water and added to the finished soap while yet hot, and before it is screened. It acts in a manner similar to glue, and gives to the paper similar qualities.

The froth which is frequently seen in the engine and on the machine when resin-size is used, is very objectionable, and numerous expedients are resorted to for the purpose of preventing its appearance. It is well known that oil, poured on the pulp, will kill the froth; and some paper-makers, probably guided by this fact, add "*tallow*" to the resin soap. An experienced manufacturer uses 7 pounds of tallow with every barrel of resin, and states that he is never troubled with froth.

63. Quality of the Resin, and Use of the Solution.—It is only natural that the darker kinds of resin should be used for lower grades, and the whiter ones for the finest qualities of paper.

The solution of resin must be strained before it is admitted to the pulp, but it is indifferent when this is done.

If any chlorine, or hydrochloric, or sulphuric acid remains in the pulp, it will immediately form chloride of sodium or sulphate of soda with the soda of the solution, and the resin, left by its dissolving agent, is precipitated.

We might as well throw pure resin into the engine as to allow the soda to be neutralized by acid contained in the pulp.

It is difficult to decide by theory if the resin soap or the solution of alum should be first mixed with the pulp. Experience is here again the best guide; and it will be found, on inquiry, that most of our leading paper-makers, if not all, mix the alum first thoroughly with the pulp, and pour in the soap only a short time before emptying the engine.

64. Alums and their Comparative Values.—No matter which one of the different kinds of alum is used, it should always be dissolved in water, and filtered through a wire-gauze or flannel into the engine to keep the impurities out.

The "*crystallized alum*" used in paper-mills consists of sulphate of potash, sulphate of alumina, and water.

$$\underset{\text{Sulphate of potash.}}{KO,SO_3} + \underset{\text{Sulphate of alumina.}}{Al_2O_3,3SO_3} + \underset{\text{Water.}}{24HO}$$

The sulphate of alumina is the only useful part of it, while the sulphate of potash and water are simply spectators and remain unchanged.

The sulphuric acid of the sulphate of alumina joins the soda and forms sulphate of soda (NaO,SO_3), which remains soluble, and the alumina and resin are deposited on the fibres as a resinous alumina.

Alumina (Al_2O_3) is the sesquioxide of the white and light metal aluminium. Kaolin or clay, which is nearly pure alumina, is not soluble in water, but its combination with sulphuric acid, the sulphate of alumina, dissolves easily.

This *sulphate of alumina* is manufactured by boiling clay and sulphuric acid directly together. The cakes thus obtained are a mixture of sulphate of alumina, clay, and water, which varies considerably in its proportions of these substances.

The atomic weights of the different parts composing crystallized alum, $KO,SO_3 + Al_2O_3,3SO_3 + 24HO$, are—

Sulphate of Potash,	$KOSO_3$	$=(39+8)+(16+24)$	$=87$
Sulphate of Alumina,	$Al_2O_33SO_5$	$=(2\times13.6+24)+3(16+24)$	$=171.2$
Water,	2440	$=24(8+1)$	216
			474.2

Of the useful sulphate of alumina there are 171.2 parts in 474.2 or

$$\frac{171.2 \times 100}{474.2} = 36.01 \text{ in 100 pounds.}$$

The sulphate of alumina in cakes is, as said before, variable, but can be put at 44 pounds in 100 pounds, while the balance consists of clay, sulphuric acid, and water.

Concentrated alum or aluminous cake contains more sulphate of alumina than crystallized alum. It is therefore cheaper at the same price per pound, but its uncertain composition has caused it to be excluded from many mills where crystals are preferred, because their proportion of sulphate of alumina is always very nearly the same.

Of late years an improved aluminous cake has been sold by the Pennsylvania Salt Manufacturing Company as "*Natrona porous alum.*"

While the aluminous cake necessarily contains all the impurities of the clay used for its manufacture, besides some clay not combined with acid, and also free sulphuric acid, this new alum is made in a way, to exclude the possibility of the presence of either of them.

Pure hydrate of alumina, precipitated with carbonic acid from an alkaline solution, which has been prepared from the imported mineral kryolith, forms the basis instead of clay.

This hydrate of alumina is mixed with the proper quantities of sulphuric acid and water in copper vessels, and their affinity is so great that the temperature of the mixture rises far above boiling heat, and causes violent ebullition. When the action has somewhat subsided a certain amount of soda is added, and the fluid mass is rapidly discharged into large flat pans, wherein it soon solidifies into cakes about 4 inches thick, and weighing half a ton or more. They are removed when cold, broken up, and crushed through suitable mills into fragments of the size of chestnuts, or a little larger, in which form the alum is packed and sold. The peculiar vesicular character of the alum is produced in part by the nature of the chemical action and partly by the skilful manipulation of the operations. Upon this porosity depends its ready solubility.

The alum is stated to be composed of—

Alumina, ...	16	parts	57 parts Sulphate of Alumina.
Sulphuric Acid, anhydrous or dry, .	41	"	
Soda, ...	2.20	"	
Water, ...	40.80	"	
	100.00		

The sulphuric acid is partially neutralized by the soda, so that the sulphate of alumina is basic; the ratio of acid to alumina being usually $2\frac{85}{100}$ equivalents of acid to 1 equivalent of alumina.

This basic condition of the porous alum is its principal advantage. It excludes the possibility of the presence of free acid, which is so destructive to some colors, especially to ultramarine.

It is perfectly white, and, being manufactured of pure materials, contains none of those salts of iron which color many other alums.

65. Necessary Quantity of Alum.—If any part of the resin soap should remain in the paper as such, it would not only be lost as sizing material, but would make spots, after the paper had been dried. It is therefore necessary to add enough alum to precipitate all the resin, and rather a surplus of it than not enough.

The resin soap, being of an alkaline nature, turns red litmus paper blue, but alum, through its sulphuric acid, turns blue litmus paper red, and it can thus easily be discovered if the pulp contains a surplus of one or the other.

If, after the alum and resin soap have been added to the pulp for some time, red litmus paper is turned blue, the quantity of alum has not been sufficient, and must be increased until the pulp turns blue litmus paper red.

It is frequently stated, that one pound of alum for every pound of resin is sufficient, but this evidently cannot hold good in all cases, as the quantity of the alone-effective sulphate of alumina in different alums is, as shown before, not the same.

As a surplus of alum cannot do any harm unless it contains free acid, the safest way is, to use too much, until the necessary quantity has been found by experiment.

The presence of alum improves or brightens a good many colors, and whenever paper of such tints is made, alum is used in profusion.

66. Sizing with Wax.—Even the cleanest resin is not perfectly colorless, and for very fine papers it may perhaps be desirable to use white wax in its place.

It is dissolved in a concentrated solution of caustic soda, testing five degrees Baumé, and is also precipitated with alum.

This method has been invented by Mr. Canson, but we are not aware that its use has extended beyond the mills of the inventor.

67. Clay.—Clay, China clay, kaolin, all of which are more or less pure alumina (Al_2O_3), have been added to paper pulp during late years to such an extent, that even manufacturers who do not approve of the practice have been compelled to use them for the sake of competition, as they lessen the cost of the paper.

Clay or alumina, has, as said before, a strong affinity for vegetable matter and adheres very closely to the fibres.

A small addition of it to the pulp may improve some kinds of paper, by making them smoother and more opaque, but if large quantities are put in, the paper becomes brittle, of little strength, and the consumers are deceived by the heavy weight. The public, who have at last become aware of this imposition, ask for paper containing little

or no clay, and test the sheets by burning. The quantity of ashes left indicates the proportion of this fire-proof material.

In some cases the interests of the paper-maker and his customer are both served by heavy additions of clay; for instance, in the case of sugar refiners, who want as heavy a paper as they can get to wrap sugar loaves in.

The paper manufacturer sells clay to the sugar refiner as paper, and the latter sells it to the consumers as sugar!

The author has made paper for this purpose which contained much more than one-half of its weight of clay, and, when lighted, burned slowly with a weak flame, leaving a sheet of nearly the same thickness as the original paper, composed almost wholly of clay, behind. It was made of a pulp of strong linen or hemp, with a large quantity of resin soap, or size, alum, and well-powdered clay.

The better the clay is divided, the closer will it adhere, and the more of it will remain in the paper. If thrown into the engine as powder, some of it balls together, is never divided, does not adhere to the fibres, and will consequently be lost before the paper is formed.

A tub furnished with water and steam-pipe, with an agitator moved by belt and pulley, and a faucet a little above the bottom, should be used for the dissolution of the clay. A certain number of buckets of clay are put in; the tub is filled up with water; the agitator started and steam admitted. The clay, suspended in water by this process, is drawn off through the faucet into buckets, and poured through fine wire-gauze into the engine. Even the best clay contains impurities, which will thus be retained on the wire.

If the tub can be placed high enough, the clay may be conducted to the beaters directly through troughs.

The clay must be put into the engine before the size, so that it can reach the fibres, and will be fastened better on to them by the size surrounding both.

It is a mistake, to add the clay after the pulp has been sized, because the resinous alumina, which is already formed, surrounds the fibres, prevents the clay from reaching them, and a large proportion of it must be lost.

On the other hand, it is evident that a larger quantity of size will fasten the clay, previously poured in, better than a smaller one. The secret of holding the clay consists in the perfect division into its smallest particles, and in the addition of size in quantities proportionate to those of the clay used. Long and tough pulp is better suited to carry it than short or weak fibres.

Some manufacturers even go so far as to mix the clay with the resin soap itself, but this is not necessary and may injure the size.

Every kind of paper will carry a small proportion of clay, say 5 to 15 per cent., without size. Papers of coarse or medium qualities are not injured by such an addition, but large amounts of clay must always be considered as a deterioration. The paper on which this is printed contains about 10 per cent. of clay.

Even if great care be taken with it, a portion of the clay will be lost, because its

heavier weight causes it to deposit, wherever it finds a chance to do so; and the more there is used, the larger is the proportion lost. By burning paper in a red-hot crucible, weighing the sheet first and then the ashes, the real amount of clay contained in it, is easily ascertained.

In some mills alum, but no size, is used to bind the clay. The clay and sulphuric acid, which make up the alum or sulphate of alumina, cannot alone envelop the clay in any way, or hold it by any other power; they are therefore utterly wasted.

Mr. T. H. Tieman has obtained a patent of invention for the addition of alum and fresh lime conjointly to paper pulp. The sulphate of alumina or alum, in solution with fresh lime, delivers the sulphuric acid to the lime, for which it has a greater affinity. Clay or alumina and sulphate of lime or gypsum are the result. Being precipitated from the solution of salts, they will be divided into their smallest possible parts and well mixed with the pulp.

The inventor claims, therefore, that a larger proportion of these substances enters into the composition of the paper than of any clay or similar materials which are only mechanically mixed with the pulp.

(d) *Coloring.*

68. White Paper.—If white paper is to be made, some color is necessary to make it appear so, even if the whitest pulp is used for it. No laundress ever attempts to finish up linen without adding some blue to it.

Mr. Richard Herring, in his work on *Paper and Paper-making*, relates the accident which originated the bluing of paper, as follows:

> "The practice of bluing the paper pulp had its origin in a singularly accidental circumstance, which, not merely as an historical fact, but as forming an amusing anecdote, is perhaps worth mentioning. It occurred about the year 1746, at a paper-mill belonging to Mr. Buttenshaw, whose wife, on the occasion in question, was superintending the washing of some fine linen, when, accidentally, she dropped her bag of powdered blue into the midst of some pulp in a forward state of preparation; and so great was the fear she entertained of the mischief she had done, seeing the blue rapidly amalgamated with the pulp, that all allusion to it was studiously avoided, until, on Mr. Buttenshaw's inquiring in great astonishment what it was that had imparted the peculiar color to the pulp, his wife, perceiving that no very great damage had been done, took courage and at once disclosed the secret, for which she was afterwards rewarded in a remarkable manner by her husband, who being naturally pleased with an advance of so much as four shillings per bundle, upon submitting the *improved* make to the London market, immediately purchased a costly scarlet cloak (somewhat more congenial to taste in those days, it is presumed, than it would be now), which he carefully conveyed home, and presented with much satisfaction to the sharer of his joy."

In a scientific sense, white is the combination of all the colors contained in the rays of the sun, the source of all our light; but it seems that the objects which we recognize as white, like snow and milk, have really a slight bluish tint. Pure water

or ice, which is commonly supposed to be white or of no particular color, has, according to Bunsen, a light-blue hue. Several colors are used for the production of this shade in paper.

69. **Prussian Blue,** ferrocyanide of iron ($3FeCy,2Fe_2Cy_3$), is produced by mixing yellow prussiate of potash or ferrocyanide of potassium ($2KCy,FeCy + 3HO$) with copperas or sesquisulphate of iron ($2FeO,3SO_3 + 7HO$). Three parts of prussiate of potash with two of copperas and two of oxygen give a blue deposit and sulphate of potash in solution.

$$\underset{\text{Prussiate.}}{3(2KCy,FeCy)} + \underset{\text{Water.}}{Aq.} + \underset{\text{Copperas.}}{2(Fe_2O_2,3SO_3)} + \underset{\text{Water.}}{Aq.} + \underset{\text{Oxygen.}}{2O} = \underset{\text{Blue.}}{3FeCy,2Fe_2Cy_3} + \underset{\text{Sulphate of potash.}}{6(KO,SO_3)} + \underset{\text{Water.}}{Aq.}$$

The crystals of sulphate of iron or copperas contain iron as a protoxide, but, when exposed to the air, take up oxygen and become a greenish, dirty-looking mass of the sesquisulphate of the sesquioxide of iron ($Fe_2O_3,3SO_3$).

This transformation is necessary, but has hardly ever been completed in the commercial copperas, and a supply of oxygen must therefore be provided for the production of a perfect Prussian blue.

The proportions used above for the explanation of the chemical changes are not those of the materials to be used, as the large quantity of water in the copperas (nearly one-half of their weight) has not been taken into account.

Yellow prussiate being very expensive, and copperas cheap, it is advisable to use an excess of the latter rather than to risk the loss of a portion of the prussiate.

All the apparatus required is an open tub, made of a well-cleaned ordinary oil barrel, one head of which has been taken out, while the other one serves as bottom.

To draw off the color, we bore a vertical row of ¾ inch holes, about 3 inches apart, measured perpendicularly, into the staves. The first hole may be about 10 inches from the top, and the lowest one 6 inches from the bottom, and they are put alternating into three adjoining staves, so as not to weaken any one too much. Each hole is provided with a wooden spigot.

We fill this tub about one-fourth full of hot water, in which we dissolve 25 pounds of yellow prussiate. In another half-barrel or bucket we dissolve 30 pounds of copperas, also in hot water, pour it into our tub, which contains the solution of prussiate, and fill up with water to the top, stirring the mass with a stick all the time. There appears instantly a light-blue substance, which deposits as soon as the liquid is left to itself.

After the mixture will have stood for several hours, a greenish watery liquid fills the upper and a blue deposit the lower part of the barrel. This liquid is drawn off by opening the holes, beginning with the top one, until the blue color appears. It is well to convince yourself that all the prussiate has been used up, by adding a few drops of a fresh solution of copperas to the first fluid drawn off. If blue color is thereby produced, it is an evidence that we have not used enough copperas, and should put more of its solution into the barrel.

We can also try if too much copperas has been used, by adding a few drops of prussiate solution to some of the liquid. If a heavy deposit of blue is obtained, the proportion of copperas may be reduced, though a small surplus of this cheap material cannot cause much loss.

In place of the drawn-off liquid we add a fresh supply of water, mix it with the blue deposit, let it settle, and run the clear fluid off again as before. In stirring the mass we bring it in frequent contact with the oxygen of the air, and thereby change it gradually into a deeper blue.

The continued washing with fresh water also removes all traces of copperas which may yet adhere to it, and the oftener it is repeated, the better.

This slow method of oxidizing the protoxide of iron into the sesquioxide (Fe_2O_2) into (Fe_2O_3), or rather, the cyanide (Fe_2Cy_2) into sesquicyanide (Fe_2Cy_3), can be improved upon, by adding to the first mixture some acid, which supplies the oxygen quicker than the air.

Nitric acid would be the best, but is expensive; and a solution of bleaching powders, which is always on hand, will do well enough. The hypochlorous acid (ClO) in the solution sets its own and the oxygen of water free, by forming hydrochloric acid (HCl), exactly as in bleaching, and explained under that head in article 35. The solution of about 1 pound of bleaching powders is necessary for 2 pounds of copperas.

After having used either one of these acids with the original mixture, clear water must be added several times to wash the deposit, as before described.

The blue sediment is then taken out, put into some other vessel or tub, and mixed with enough water to fill it to a certain point (usually the top).

If the blue were kept uncovered, it would constantly lose water by evaporation, the solution would become more concentrated all the time, and a certain volume of it, which is measured out to every beating engine for the production of paper of a certain color, would tint it deeper every day. The vessel must therefore be well covered, and the blue deposit obtained from every 25 pounds of prussiate (or any other quantity which may be fixed upon as the regular dose) must be diluted so as to fill it to the same point.

For common white papers, such as news and others, this blue answers equally as well as ultramarine, and does not cost one-third as much. The manufacture of the lower grades of white paper is often so much hurried that sufficient time is not taken to wash out the bleaching liquor, and while their presence in the pulp would be destructive to ultramarine, it would rather improve Prussian blue.

Any alkaline solution would injure this blue; the resin soap should therefore only be added to pulp containing it, after the alum has been mixed with it; or the paper may be colored after it has been completely sized. A surplus of alum will then serve as a mordant, and intensify the color.

Prussian blue is manufactured and sold in pieces, which must be redissolved, but

its preparation, as described, is so simple that it can be made by any one of the workmen, and certainly at less expense.

Prussian blue has always a greenish tint, which is objectionable in fine papers, and ultramarine is therefore generally used for them.

70. Ultramarine.—For centuries past the ultramarine color has been used by artist painters. It was prepared from a rare mineral, the lapis lazuli, by powdering and washing it.

Professor Gmelin, of Heidelberg, analyzed this mineral carefully, and succeeded, after numerous experiments, in producing artificial ultramarine, very little inferior to the natural one.

The manufacture is too difficult and complicated, to be carried on in a paper-mill, and therefore beyond the intended limits of this book; but it may be stated as a matter of general information that the raw materials, from which ultramarine is made, are sand, alum, clay, charcoal, sulphur, and soda. All of them are cheap; and let us hope that this valuable color will be obtained in future times at rates considerably below the present ones.

Artificial ultramarine is chemically composed of silicate of alumina and soda with quinsulphuret of sodium:

$$4NaO,4A_2O_3,9SiO_3 + NaS_5.$$

The coloring power of ultramarine varies very much, according to its manufacture. It is a very heavy material which does not dissolve, but colors the mass of the paper by being diffused through it in small particles. The blue which is most uniformly distributed, or the one reduced to the finest powder, must be most effective if the mass from which it is made is equal to the others. If the powder has not been carefully sifted, some larger particles remain in it, and either leave the pulp through the wire or in some other part of the machine, where they may settle down through their weight. If they remain in the pulp they must inevitably show on the paper as blue spots.

Carl Furstenan has found by microscopic examination of fine brands of ultramarine (*Centralblatt für Deutsche Papierfabrication,* 1871, No. 21) that they consist of—

1. A blue-colored, drossy, gloss-like mass.
2. Lively dark-blue grains, of which the coarse ones have a white kernel.
3. Unaffected kaolin and an uncolored enamel-like substance.

The more it contains of the fine grains No. 2, the better the color, and the less will the ultramarine be affected by alum. All of No. 3 is useless.

With the aid of the microscope the difference in the fineness can easily be discovered, but the only conclusive practical test is made in the engine. The ultramarine, of which the smallest quantity is required, to produce a certain shade of blue in the same quantity and kind of pulp, is the best.

To keep out impurities and coarse grains, it should always be filtered through a silk or flannel bag.

This is done by filling in the necessary quantity, and then pressing it with the hands through the bag while immersed in a basin of water.

All acids decompose ultramarine. If the pulp shows any acid reaction, be it from chlorine, alum, or any other source, it should be made neutral or basic by the addition of some soda before the ultramarine is put in.

Since it colors the pulp only by thorough mechanical division, it should be given plenty of time to mix with it.

71. Indigo Blue, formerly much used, is now hardly ever found in paper mills.

72. Aniline Colors.—Aniline is a substance composed of carbon, hydrogen, and nitrogen ($C_{12}H_7N$), manufactured on a large scale from coal-tar. It forms the basis of a number of so-called aniline colors, which are made from it, and amongst them also a blue one.

I. *Aniline Blue,* as obtained by the trade, looks rather like a bronze paste than crystals, as it is commercially called. It is dissolved in hot water, one ounce to a gallon, at the mill, and care must be taken that the pulp contains no free acid, as the color will be destroyed by it.

It requires no preparation, and is very extensively used for colored papers. With aniline red it makes a handsome purple, and, like most aniline colors, produces shades of a tender hue heretofore unknown.

Ultramarine mixes only "mechanically" with the pulp, but aniline blue in solution pervades the stuff thoroughly, and may be called "chemically" combined with it.

II. *Aniline Red.*—The paper, which is made without any admixture of blue, always has a yellow tint, and the blue will not therefore produce the pure white, which we desire.

Paper colored with blue alone looks slightly greenish, and to overcome this a very small proportion of some red is used.

The aniline red answers this purpose very well; it is dissolved like the blue, one ounce in a gallon of hot water, and put directly into the engine. It is rather of blood color, but can easily be turned more purple by the addition of some alum.

III. A large variety of other shades of aniline colors besides blue and red are manufactured. The yellow and orange aniline colors cannot, however, compete with the chrome colors as to intensity, and only find favor for light tints.

73. Pink or Cochineal Red.—Pink or cochineal is made from the shells of a very minute insect found in Mexico.

Many methods of extracting the carmine are recommended and used, but we shall content ourselves with describing one of them, as many paper-makers prefer to buy the extract ready made. Parties engaged in making colored papers as a specialty will, however, find it to their advantage to prepare the color from the shells.

Ten pounds of cochineal, ground into small pieces in a coffee-mill, are mixed with 25 to 50 gallons of water, made slightly alkaline by the addition of about $\frac{3}{4}$ pound of crystals of soda, and boiled in a tub furnished with a steam-pipe. The solution thus obtained is filtered through a wet felt into a tub, provided with spigots

in the same way as the barrel wherein the Prussian blue is made,—but the tub must be more capacious than the barrel.

The shells are treated three times in this way, and the three extracts gathered into the same tub.

To this solution we add $8\frac{1}{2}$ pounds of crystals of bichloride of tin.

The pink color carmine is thereby precipitated. After a few days' rest we draw the clear liquid off; mix up with fresh water; draw off again, and take the carmine out into glass bottles or carboys.

The cochineal may be boiled again with alkaline water, to see if any more carmine can be extracted.

74. Brazil-Wood.—Brazil or Pernambuco wood is commercially obtained in rasped condition, and can be tested as to its quality by simply immersing it in water. The genuine article is heavier than water, and will sink, while other woods, if mixed in, will float on the surface.

The wood is first washed in lukewarm water; then boiled for a couple of hours in about ten times its weight of pure water, and the solution is filtered through a felt. An addition of $\frac{1}{4}$ pound of protochloride of tin for every pound of wood precipitates the pink color. The sediment is washed in the same way as carmine until all traces of acid have disappeared. This first decoction gives a fine red color.

To extract the remainder we have to add two parts of soda for 100 of wood to the water in which it is to be boiled. This second extract is to be treated like the first one, but furnishes, according to Proteaux, only an orange-brown color.

If only one medium quality is desired, additional extracts may be made, as long as a precipitate can be obtained, and mixed together in one receiver.

This color improves by age.

75. Violet color is obtained from logwood by treating it in the way indicated for Brazil-wood.

76. Chrome Yellow and Orange.—Chrome yellow is made from a mixture of chromate of potassa ($KO,2CrO_3$), and acetate of lead, called sugar of lead ($PbO,C_4H_3O_3+3HO$), or nitrate of lead (PbO,NO_5). When both solutions are in contact, a soluble acetate or nitrate of potassa, and an insoluble powder of chromate of lead of a beautiful yellow color (PbO,CrO_3), are formed.

The nitrate of lead is now manufactured and sold to the trade in white crystals, and has nearly altogether taken the place of sugar of lead, because its action is more intense.

One pound of sugar of lead, with about $\frac{1}{2}$ pound bichromate of potash, gives a good yellow color.

The chromic acid and lead form also another union, consisting of two atoms of lead and one of chromic acid ($2PlO,CrO_3$) of a red color.

The bichromate of potassa is manufactured in orange or reddish-colored crystals, and the color changes more into orange as larger proportions of it are used, while the yellow becomes more intense with every increase of the nitrate of lead.

It seems that some of the red subchromate of lead is formed, wherever an abun-

dance of bichromate is present, and the red and yellow together give orange. The same object can be attained by increasing the proportion of lead in the acetate or nitrate, and thus transforming it partially into subacetate or subnitrate. For this purpose one pound of sugar of lead is boiled for one-half hour with one pound of oxide of lead or litharge. The undissolved litharge separates as a deposit, and the liquid contains some subacetate of lead in the place of sugar of lead. It more readily forms the subchromate of lead, and thus produces a very pretty orange. Rain-water is preferable to well-water for this operation.

The pulp is colored orange or yellow by dissolving the different chemicals separately in hot water, and then putting them in the engine, giving time enough, however, to the first one to impregnate the stuff thoroughly before the other is added. A uniform distribution all through the mass is evidently best obtained when the color is formed in the engine.

Sometimes, however, especially for light shades, it is preferred to finish the color outside, and then put it in the engine, because it can thus be better controlled.

For a good light yellow, for instance, $1\frac{1}{2}$ pounds of bichromate and 3 pounds of acetate or nitrate of lead, per 100 pounds of paper, are separately dissolved in hot water; then mixed; the clear liquid drawn off, and the yellow sediment put at once in the engine.

If orange is to be made, a larger proportion of bichromate has to be used; both are dissolved and mixed in the same way. After the clear liquid is taken off, some soda is added to the color, and it is left undisturbed for some time.

The longer it is allowed to rest undisturbed the deeper orange will it become.

77. **Orange Mineral** is an orange-red combination of lead and oxygen, similar to red lead, but prepared with more care. It is simply thrown into the engine to intensify the orange, or to make salmon and similar shades with the chrome yellow.

It gives a deep and intense color, and is very extensively used.

78. **Buff** for common papers is made from copperas (sesquisulphate of iron) by neutralizing its sulphuric acid with a solution of some alkali, caustic or burnt lime, or milk of lime, thereby precipitating a kind of iron rust or oxide of iron. To obtain all the color or iron from the copperas, it is necessary to add milk of lime until the pulp is neutral, and neither turns blue litmus paper red nor the red paper blue. If, by mistake, too much lime has been added, some vitriol will neutralize it again.

Ten pounds of copperas per hundred of paper thus give a leather buff color.

Proteaux recommends for light buff, 5 parts sulphate of iron, 3 parts of soda, or 2 of chloride of lime.

For dark buff, 16 parts of sulphate of iron, 9 parts of soda, or 6 parts of chloride of lime.

Fine papers are colored with a buff composed of chrome orange, orange mineral, and ochre.

79. **Venetian Red** is an earth color, and can be used, if well washed, for delicate brown and leather colors, but large quantities of it in the original state enter into the composition of the lower grades of paper, such as wrapping, for instance.

80. Yellow Ochre, as well as numerous other earth colors, must be enumerated here as belonging to the stock of coloring materials of a paper-mill.

81. Quercitron or Oak Bark is frequently used for mixed colors, such as tea or browns and others. It is furnished to the trade rasped, and its specific gravity varies with the quantity of wood which is attached to the bark. The wood contains no color, and is useless, but heavier than the bark. It is therefore safer to measure the desired quantity than to weigh it, as the same volume of the rasped bark is more likely to return the same color than the same weight. One gallon of bark well boiled in two gallons of water will furnish a good extract. It gives alone an inferior yellow color, but is mostly used with a solution of copperas, which changes it into olive-green.

82. Nutgalls or gallic acid ($C_7HO_3 + 2HO$) are crushed into small pieces and boiled with water. The clear solution is drawn off and gives, with copperas, an ink-like gray color.

83. Black.—Lampblack is freed from greasy matters by repeated washings, with soda-ash solution first and clean water afterwards; the liquid is decanted, and the deposited black powder mixed with the size, before the latter is added to the pulp.

Perfectly black paper is hardly ever made in the pulp, but gray and its combinations are often produced with this lampblack.

84. Colored rags or paper used to be the only means of coloring the pulp, before the art of bleaching was introduced, and even now some paper-makers sort out the blue and red rags separately for this purpose. This is much more justified for the red ones, as their madder color is very difficult to destroy or bleach. Their absence benefits the balance of the rags, while their color can be made useful for red paper.

The blue color is easily bleached out of the rags, and is not worth preserving, considering that we must have clean white pulp to make a well-colored paper.

In some cases, where a very deep-colored blue paper is wanted, or for blue wrapping paper, it may however be of advantage to use blue rags which have been neither boiled nor bleached.

85. Combination of Colors.—We have in the foregoing lines enumerated the primary colors used by the paper-maker; but to comprehend their endless combinations and to perfect them intelligently, the nature of colors generally should be understood.

If the rays of the sun—the source of all our light—are dissolved by a prism into their component parts, we find them to consist of all the colors known to us. This leads to the conclusion, confirmed by experiments, that all these colors mixed together must produce white.

All the sounds which we hear can be reduced to three fundamental ones, and likewise we have three primary colors corresponding with them. They are yellow, red, and blue, with a relative strength of 3, 5, and 8 respectively.

If 3 yellow, 5 red, and 8 blue rays could be directed on some solid body which would reflect them thoroughly, the body would appear to us white, and if they were all absorbed, it would look black.

The primary colors,

> Yellow and red, in the proportions of 3 to 5, give orange;
> Red and blue, in the proportions of 5 to 8, give purple;
> And 3 yellow with 8 blue make green.

These are the secondary colors.

Mixtures of the primary colors in different proportions produce all kinds of shades, and their combinations with secondary colors furnish the countless varieties with or without names which daily meet and surprise our eyes.

Green paper is made by mixing blue and yellow with the pulp, while purple is produced from blue and red, &c.

Knowledge and experience are necessary to decide the composition of a color when no other guide than a sample is given, as is very often the case. If a combination has been found which seems to answer, it is important to find out if the pulp in the engine is exactly like that of the sample before it is emptied and run over the machine.

Colored paper, when finished, appears very different from the pulp in the engine, and a comparison of a sample of paper with the stuff in the beaters would be quite useless. Both the new paper or pulp and the sample, must be in the same condition of moisture and preparation when compared. Some of the colored stuff in the engine can either be made into paper on a mould, and then pressed and dried by hand, or a piece of the sample must be transformed into pulp. The latter method is the quickest, and therefore usually followed: the piece of paper is macerated in water and mashed up or chewed by the operator, so as to form a paste, and some of the new pulp is pressed out by hand, until both are at about the same state of moisture. A comparison of them shows if we have too much or too little of some color in the engine, and enables us to improve the composition, until it is as desired.

86. Examples of Combination of Colors.—We have given a list of the principal primary colors and a guide for their use, so that any man of ordinary ability should be able to make colored paper; but we might fill a book with prescriptions of combinations without giving all possible varieties.

Some mixtures, however, are made in such large quantities that a knowledge of them may be useful to many manufacturers.

We give them as they are made by paper-makers who have gained for their colored papers a merited reputation.

Yellow-gold envelope of fine quality is made of—

Bichromate of potash,	10 pounds,
Nitrate of lead,	18 "
Orange mineral,	56 "
Porous alum,	30 "

each separately dissolved, and added to 400 pounds of paper pulp.

Orange-red gold envelope is obtained from—

Bichromate of potash, ...	7 pounds,
Nitrate of lead, ...	$10\frac{1}{2}$ "
Orange mineral, ...	60 "
Porous alum, ...	20 "

each separately dissolved, and added to 400 pounds of paper pulp.

Buff envelope of a fine deep shade is made of—

Bichromate of potash, ...	3 pounds,
Nitrate of lead, ...	5 "
Orange mineral, ...	10 "
American ochre, ...	20 "
Porous alum, ...	30 "
Some half-stuff of red jute-bagging,	

for 400 pounds of paper.

Tea-color is made from a decoction of quercitron bark, made as before described. This liquid is poured into the engine, and two pounds of copperas are added for every gallon of the bark extract. A little ultramarine may be used to brighten the color.

Drab.—Venetian red, well washed, added to a pulp of tea-color, made as described, will give a fine drab.

Brown is always composed of several other colors, a very fine dark tea-color brown, containing tea, buff, drab, and ink-gray, is made of—

Quercitron bark liquid, ...	15 gallons,
Bicarbonate of soda, ...	2 pounds,
Venetian red, ...	4 "
Nutgalls in extract, ...	$2\frac{1}{2}$ "
Copperas, ...	18 "
Porous alum, ...	30 "

for 400 pounds of paper.

The large proportion of alum, prescribed in all these examples, serves as a mordant, and also, with the addition of resin soap, for sizing.

The tinted paper of this book was made by M. M. Curtis & Brother, at Newark, Delaware. It is colored with—

Yellow, French ochre, ...	$2\frac{1}{2}$ pounds,
Orange mineral, ...	1 "

for 325 pounds of paper; each separately stirred up in water and strained through No. 60 wire-cloth into the beater.

87. Mixing the Coloring Materials with the Pulp.—If the paper is sized in the pulp, resinous alumina surrounds the fibres and prevents a thorough penetration by the coloring materials which may be afterwards added. These materials are, then, only loosely held, and a portion must be lost on the machine.

If they are added to the pulp before it is sized, they become thoroughly mixed with the fibres, and with them enveloped by the size.

Though the section on sizing precedes that on coloring in this book, the pulp should always be colored before it is sized, except in cases where the alum or resin soap would injure the colors or be injured by them.

All coloring materials should, as well as the water, size, and clay, be strained before they are admitted to the pulp.

While the pulp is being sized and colored, the finishing touch is given by the engineer, who then examines it, as before described, and empties it into a stuff-chest.

If a patent engine is used, the last grinding is given to the rags by it, and the pulp is only mixed and prepared for them by the beaters.

(e) *Patent Pulping Engines.*

88. Kingsland's Pulping Engine.—T. Kingsland, of Franklin, Essex County, N. J., received patents of invention in 1856, renewed 1871, for an engine which was designed to do nearly all the work of the beaters, except the washing and mixing. In the mills of T. & R. Kingsland this engine is furnished with rags, which have been beaten little more than half-stuff, and the papers, made by it, range among the best qualities of book and flat-cap in the New York market.

The "half-stuff" descends through the pipe B, Fig. 44, and passes into a circular chamber, the sides of which are formed of two plates O Q, provided with steel teeth; these are stationary, and can be brought closer together or placed further apart by the handle and gearing, G, A, C, E, so as to grind the "half-stuff" in pulp of the desired length of fibre. The threaded bolts V, passed through lugs D, bring up the plate O, while F forms guides for E. Between O and Q a plate P is placed; it has steel teeth on both sides, and is rotated rapidly between them by a shaft and belt. This shaft works in journals, and has no collars, so that it can adjust itself to the varying distances between the outer plates. The pulp, when ground, passes through a pipe I in a continuous stream into the intermediate receiver H, and from that directly through a shute J, or over a strainer K, to a "stuff-chest" in any convenient location.

Fig. 47 shows, that the steel knives are disposed in a manner, to give to the plates the appearance of millstones. The plates O and Q represent stationary stones, and P the revolving one; the pulp enters at the centre of O, proceeds to the circumference, and leaves near the centre of Q.

The steel knives are cast in the plates, from which they project about ½ inch, and the space between them is filled with wood. This wood is gradually chiselled out, as the knives wear down; but when all of it is removed and the knives are used up to the base, the plate can no longer do any work, and a new one must be put in its place.

The plates are of 30 inches diameter, and carry more and stronger knives for hard stock, such as rags, than for short material like straw or imperfections.

The revolving plate P, studded with knives on both sides in the manner shown by Fig. 47, should make from 200 to 250 revolutions per minute, and moves with its shaft to and fro between the stationary plates O and Q. The pulp surrounding it, if of uniform composition, will keep it in the middle between the two. The space between the revolving and stationary plates, or the distance between the knives, is increased or decreased at will by turning the crank G.

FIG. 44.

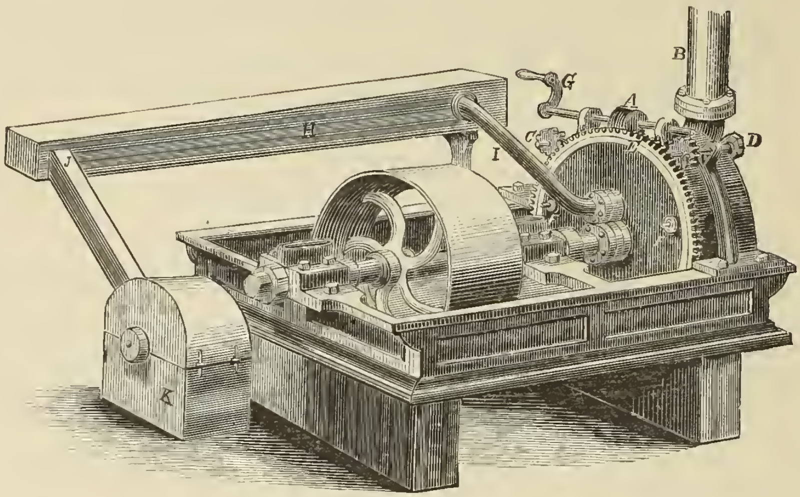


FIG. 45

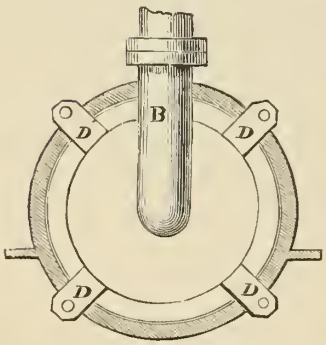


FIG. 46.

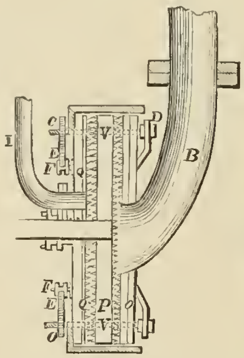


FIG. 47.

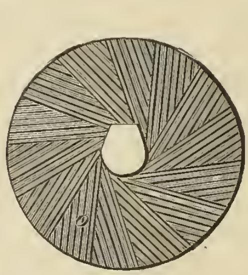


FIG. 44 is a perspective view of the engine.
FIG. 45 is an elevation of the front or feed side.
FIG. 46 is a vertical cross-section.
FIG. 47 is a plan of the plate O.

The crank G, with the worm-gearings and threaded bolts V, by means of which the front plate O is moved in or out, may, as they perform the same functions, be compared with the lighter of an ordinary beating engine.

It is here where the man in charge has to use his judgment, and he is guided by the appearance of the pulp flowing through pipe I and trough H, as well as by the

sound. By putting his ear to the crank G he can distinctly hear the noise made by the grinding plates.

If the pulp on leaving the engine is too short, the front plate O must be moved out, and if it is not ground enough, the plate should be moved in.

It is claimed for this engine that it saves power, though it consumes about 20 to 25 horse-power on rag pulp, also that it furnishes a more uniform paper, and a larger quantity of it, than ordinary beaters.

To understand its action we shall now follow the pulp on its passage through the engine.

The pulp enters from a pipe B through the centre of the front plate O, and is quickly spread against the periphery by the centrifugal power, which is communicated to it by the revolving plate P. The motion of the knives in the centre is slow, but increases with the diameter, and thus tends to throw the principal part of the grinding action near to the circumference. But, after the pulp has passed around the revolving disk, and entered between it and the plate Q, its flow to the discharge-pipe I is retarded as much by the same centrifugal power as it was before increased. In fact, the pulp would hardly be able to leave the engine, if the discharge opening were not somewhat out of the centre, and if the pulp were not fed from a trough, a few feet above the engine, through pipe B. The height from which the pulp descends determines therefore, to some extent, the quantity which can be passed through the engine.

Centrifugal power is proportionate to the speed and the weight of the moved body. Large or heavy fibres are therefore forced to the circumference, and held there, while small or light ones are able to escape.

The current also carries reduced fibres much easier and faster than long or heavy ones, and thus the finished pulp marches right through the engine, while the coarse portion is held back till it has been ground into the desired state.

If a knot or lump of fibres should be fed into the grinder, the disk P would yield and move back towards the plate Q, to make room for the passage of the knot towards the periphery, where it would be quickly reduced by the energetic action of that part of the engine. While this reduction of the knot is going on at the front side, the revolving disk P is crowded over against the discharge opening, and reduces the outflow of pulp. The yielding of the disk thus not only prevents all danger of clogging, but also the escape of any unground fibre.

If the fibre is tender and easily reduced, it will flow freely through the grinder, and occupy but little more space on the feed-side than on the discharge-side of the disk, but if the fibre is tough and slowly reduced, it will accumulate on the feed-side, crowd the disk back, and retard its escape. The stronger fibre is through this action subjected to severer grinding than the weaker one—as it should be.

This is considered one of the principal features of the invention, and explains why it should furnish uniform stuff.

Sometimes strings, rags, or pieces of wood or metal are carried into the engine with the pulp and obstruct its flow.

All such substances lodge usually in the centre of the plate, and whenever their presence is indicated by a decreased discharge of pulp, the plate O must be unscrewed and taken off, and the obstructions removed.

As the engine requires considerable power, the driving belt should not be less than 12 inches wide.

In order to do its duty well, it must be kept in good condition; the plates must be sharp, and promptly renewed when worn out. It has been frequently condemned when nothing but the neglect of the owner was the cause of the failure.

After the pulp has been washed and mixed with size and color, and about half beaten in the ordinary engines, it is emptied into a stuff-chest. A stuff-pump takes it from there and throws it up into a horizontal trough above the Kingsland engine, with which it is connected by the pipe B. This trough has an overflow regulated by a sliding gate, over which the surplus pulp returns through a spout into the chest. The supply is thus governed to some extent by this sliding gate.

Mr. Kingsland uses a capacious plunger-pump with rubber valves, which offer no obstruction to the passage of strings and rags, but ordinary stuff-pumps, with brass ball valves, supply also many of these engines, and answer very well.

The pulp flows from the discharge pipe I, either directly to the machine or into another stuff-chest. In the first case the patent engine should be connected with the paper machine, and driven by the same motor, so that both will stop and start together.

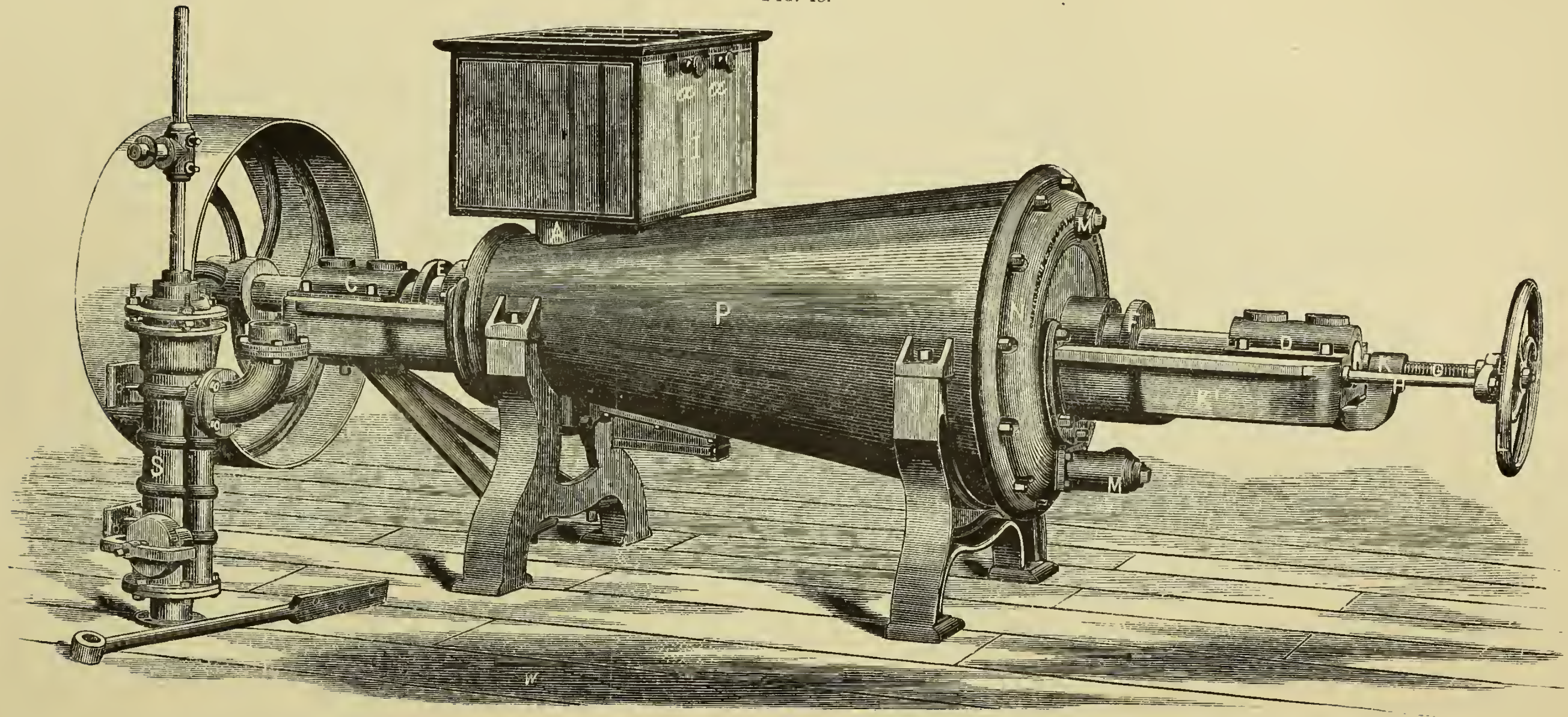
If the patent engine, as is usually the case, is located on the same floor with the beaters, and driven by the same shaft, it must be made to empty into an independent stuff-chest, from which the machine may be supplied by means of a second stuff-pump.

The last work of the beaters is to brush the pulp so that it will felt freely, and produce a uniform sheet on the wire. This most important and difficult part of the engineer's work may be done with advantage by the Kingsland engine, and, if managed properly, it will do it well.

89. Jordan's Pulping Engine.—Mr. Joseph Jordan, at present superintendent of the Ashland Paper Mill at Manayunk, Philadelphia, and Mr. Thomas Eustice, of Hartford, Connecticut, have received a patent of invention, dated May 18th, 1858, and recently extended, for a pulp-beating engine similar in principle to that of Kingsland's. The following cuts (Fig. 48 and Fig. 49) represent the engine complete and in detail, as built by Messrs. Smith, Winchester & Co., South Windham, Connecticut.

The half-stuff is fed in through the box I, which is an ordinary regulating box, like those which are used for paper machines. The pulp is thrown by a stuff-pump into the middle partition, flows into the engine from one of the side partitions, and the surplus returns to the chest through the other. The copper gates, by which the distribution of the pulp from the middle to the two sides is regulated, are operated from outside by the knobs *a a*. From this box the half-stuff flows through the inlet A into

FIG. 48.



the conical case P, which may be called the plate; a conical roll R, fitting this plate, revolves inside of it, carried by bearings C and D, and is provided with stuffing boxes E and F. Bearing C is stationary, and allows the shaft to move longitudinally through it; bearing D is connected with the shaft, and can be moved with it towards P by means of the screw G, which is itself supported by the stay-bolts H H and the nut-bracket K.

The surfaces of the roll R and plate P can be brought nearer to or separated from each other by a few turns of the hand-wheel L attached to the screw G.

The conical shape of the roll and plate, with the speed of the roll, causes the pulp to be drawn through the engine from the small to the large end by centrifugal power, and the roll shaft follows this movement as far as the screw G will permit.

Three outlets M M′ M′ are provided for the discharge of the pulp; the one which is used, is furnished with an elbow-pipe M, and the other ones are plugged. They serve to regulate the quality of the pulp; if, for instance, a very nice and uniform quality is required, the roll is drawn off from the plate, so as to lightly brush the pulp, and the upper outlet is used for its discharge. By drawing at this point, the flow of the pulp through the engine is somewhat retarded, which keeps it longer between the knife-surfaces, and thus helps to accomplish our object. If an extra quality is not required, it is customary to use one of the lower outlets, and thus increase the production of pulp.

The cast-iron head N is fastened to P with numerous screws. S is the stuff-pump which forwards the pulp from the chest to the box I.

The cast-iron roll R is 49 inches long, with a diameter of 12 inches at the small end, and of 26 inches at the large end. The part of the knives which projects above the surface of the roll, is of steel, and the balance of iron. They are planed to fit the dovetailed grooves in the roll, into which they are driven from the large end.

Thirty-six knives or fly-bars are as long as the roll, and another set of the same number extends only over one-half of the roll, thus doubling the cuts or the grinding capacity at the larger end.

The knives in the bed-plate P are made of steel of the best quality; they are elbow-shaped, and form three sections, with 37, 76, and 108 knives respectively. They are not fastened to the casting, but only secured with wooden filling and keys.

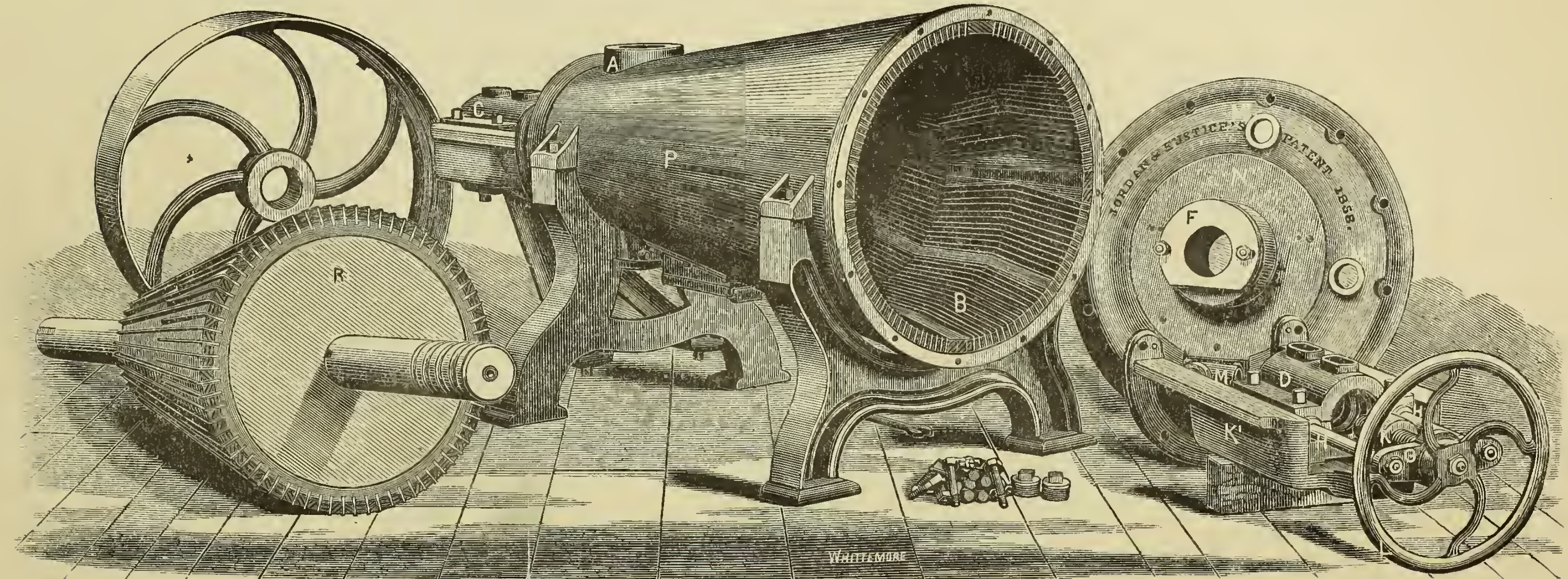
The wood between the knives of the plate and roll does not consist of solid pieces, but of flat thin strips, which are glued together. Whenever the knives are worn down, so that some of the filling must be cut out, it is only necessary to start the glued joints with a chisel, and take out one of the strips.

At Messrs. Warren & Co.'s Cumberland Mills, near Portland, Maine, the knives are made of chrome steel, which is harder and has been found to last longer than any other.

It is impossible to set the knives in this engine perfectly true with ordinary tools alone; they must be ground with sand in the engine, or turned in a lathe before they can be put in operation.

The roll makes from 200 to 300 revolutions per minute, and the engine con-

Fig. 49.



sumes from 15 to 30 horse-power, according to its speed, the quality and previous preparation of the pulp.

90. Respective Advantages of the Kingsland and Jordan Engines.—The Jordan Engine is claimed to have the following advantages over Kingsland's:

The pulp in the Kingsland engine must, just before leaving, occupy a smaller space in the centre of the back-plate, is necessarily concentrated there, and subjected to a severe grinding; while in Jordan's the diameter, and with it the speed of the pulp, is constantly increasing, the pulp is drawn out as it advances, and better opened for the action of the knives. The Jordan engine therefore furnishes a more free and uniform pulp.

In the Kingsland engine the knives cut nearly at right angles, while at acute ones in Jordan's. The latter can therefore do more work with the same power.

Jordan's engine has a grinding surface of 22½ square feet, or more than double as much as Kingsland's, and one of them can supply two paper-machines.

The Kingsland engine is claimed to be preferable to Jordan's for the following reasons:

The revolving disk regulates itself and yields to knots or lumps, while the cone of the Jordan engine can only be regulated by the screw.

The plates can easily be renewed at the mill with but little loss of time, while the knives of the Jordan engine must be taken out and renewed singly, and then either turned on a lathe or ground with sand.

The mills cannot afford to stop while the Jordan engine is being refitted, and it is therefore necessary to have a surplus Jordan engine on hand, ready to take the place of any worn out one, while a few knife-plates only are to be provided for the Kingsland engine.

Kingsland's engine, being smaller, requires less power and is sold cheaper.

Both of these patent engines are excellent to brush the pulp; but, though they are used for rag-pulp in some of our largest paper-mills, they have found more favor for straw, wood, and old paper than for hard stock.

They are hardly ever seen in either wrapping or writing-paper mills, and seem to be more suitable for medium qualities, such as news and book papers.

About one hundred engines of each kind are in operation and owned by experienced and successful paper-makers.

Each system has its friends, who give it the preference over its competitor. We have tried to set forth the merits and demerits of both, so that the reader may be able to judge for himself and make his selection accordingly.

91. Gould's Patent Engine.—The latest pulping engine, invented by Mr. Simeon L. Gould, of Gardiner, Maine, consists, according to the specifications of his reissued patent, dated July 16th, 1872, of a stationary horizontal plate, on which another one revolves, fastened on a vertical shaft. These plates seem to be similar in construction to those of the Kingsland engine, but they are larger and located on the bottom of a large iron tub or vat. The pulp enters between the plates, through an opening near

the centre of the upper revolving plate, and is thrown out at the periphery. The vat has the form of an apple, and the pulp, on leaving the grinders at the periphery, follows the hyperboloidal sides, and is directed from all parts towards the centre of the revolving plate, producing an active circulation, which makes the use of the paddle unnecessary.

This engine differs from those previously described principally in being filled and emptied periodically, like an ordinary beater. It does the work of the latter completely, as it requires no mixing engines, and is furnished with half-stuff directly from the drainers.

(f) *Stuff-Chest and Stuff-Pump.*

92. **Stuff-Chest.**—The pulp is emptied from the beaters into large circular receivers, furnished with agitators. These stuff-chests are usually made of wood, the staves being from 2½ to 3 inches thick and from 5 to 8 inches wide—a little wider at the bottom, so that the iron hoops can be driven down to tighten the tub as the staves shrink. A chest of about 12 feet diameter, 6 to 8 feet high, will hold sufficient pulp to make about 1000 to 1200 pounds of paper.

Where durability and security against fire are considered of more importance than cheap construction, they are built of brick and cement, like drainers.

An iron or wooden shaft stands upright in the centre, extending above the cover of the chest. It carries at its upper end a large bevel-wheel, moved by a pinion and pulley on a horizontal shaft.

Two horizontal arms, which extend nearly across the whole chest, are fastened to this upright shaft: one near the bottom and the other above the middle. They serve as supports to a number of upright wooden posts of nearly the height of the chest.

The object of this agitator is to keep the stuff in motion, so that the heavy parts cannot separate themselves and lodge on the bottom.

A very insignificant amount of power or number of turns is required to do this—much less than most of them are making. One revolution per minute for large chests and short pulp, and 2 or 3 for small tubs and heavy fibres would be sufficient.

Any surplus of motion above that required to float the mass is not merely a waste of power, but a positive evil. A rapid circulation causes the fibres frequently to roll up into little balls, which are not only so much lost pulp, but also obstruct the screens and mark the paper.

The agitator assists sometimes in creating this difficulty, if it is so constructed that it beats flat against the stuff. Every part of it should be formed so as to cut the pulp with a sharp edge, and no two bars should follow each other in the same track. Few and far between is the best rule for the number of upright pieces—no more than are required to keep up the movement. The sharp edges also catch the strings, which lay themselves around them and can be removed when the chest is empty, while they would slide off from round-edged pieces.

The chest must be perfectly smooth inside, and not offer any corners or projections where the fibres can lodge.

A slimy mass sticks to the sides of the chest, even if they are perfectly smooth, and should be washed off. This can easily be done by fastening on top of the upright centre-shaft a cup or pot, from which issues a ½ inch pipe, supported by the agitator, and extending to within about 1 inch of the sides. If the cup or receiver is supplied with a small stream of water, it will be thrown through the pipe against the sides with sufficient centrifugal power to keep them all the time clean.

The chests should be frequently emptied and cleaned out. The bottom must for this purpose be provided with a small valve, through which the wash-water escapes.

93. Mixture of the Pulp in the Stuff-Chest.—The paper-machine receives a certain volume of pulp with every stroke of the stuff-pump, and this mass is expected to make a certain quantity of paper of a certain weight. But it can only do so if it contains all the time the same quantity of fibres, or if the stuff in the chest is in the same state of dilution.

After the large body of pulp has left the beater, the remaining portions are washed out with fresh water, and it is usually left to the engineer to determine the quantity of the latter. The most careful man cannot always draw exactly the same quantity of water, if guided by his judgment alone; and Mr. Planche proposes therefore to establish a water-receiver above the beaters, from which a measured number of inches is to be used for every engine of pulp.

The half-stuff, furnished to every beater, cannot be expected to contain always the same quantity of fibres or paper, and here is another source of irregularity. By uniting the pulp of several beaters, the surplus of one will make up for the deficiency of the other; and the more of them we can mix together, the more uniform will be the stuff. The larger therefore the chests, the better.

If only one chest is on hand, the beaters empty into it, while the machine is supplied from it. We may suppose that the contents of a beater, together with the water used to wash it down, will give a stuff of about the same dilution as that with which they are going to mingle. But it takes, if done never so quickly, some time to empty; and while the first thick part of the pulp goes down, the stuff pumped to the machine will be more concentrated and make too heavy a paper, until the required dilution has been re-established by the mixture of the following thinner portions and the wash-water. This can only be avoided by the possession of at least two stuff-chests. While the engines are emptying into one, the machine works from the other, and nothing can change the composition of the stuff.

Few mills make one kind of paper all the time; many have to change quality or color very often. If only one chest is on hand, the beaters must wait until it is worked, and sometimes even washed out, before the succeeding kind of paper-pulp can be emptied. The time lost in this way may be saved by the comparatively small outlay for a second chest.

In mills where many different qualities or colors are made, even three or more stuff-chests will be found useful.

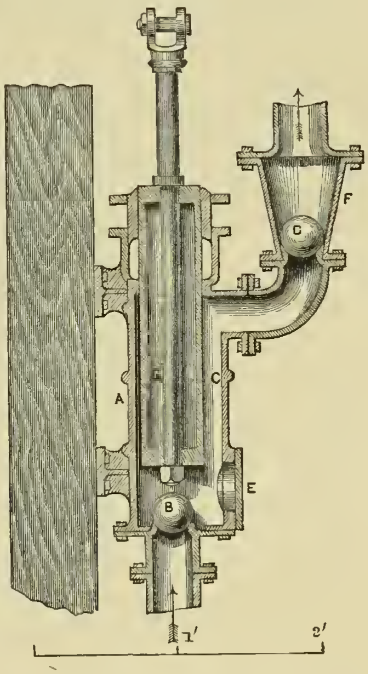
94. The Stuff-Pump.—The stuff-chests are sometimes standing on a high founda-

tion, 3 to 5 feet above the floor, and empty through gates into a small receiver, whence the pulp is either taken out by a scoop-wheel or some of those numberless contrivances called regulators, and delivered on to the machine.

The object of all these arrangements is to furnish exactly the same volume of pulp during a certain time, and none of them does it more perfectly than the plunger stuff-pump which is generally used in the United States.

This pump, represented by the following cut, Fig. 50, consists of an upright iron body A, lined with brass, with an iron, brass-lined plunger G, moved up and down in it by means of a pitman and crank, and making a stroke variable from 8 to 12 inches. Whenever the plunger goes up, the vacuum created below is filled up by the pulp, which enters through the brass ball-valve B. In descending, the pressure, exercised by the plunger, closes the valve B, and forces the pulp through the channel C and valve D into the pipe or spout leading to the regulating box. Balls are the only valves which will close, no matter in what position they fall back on their seats. Sometimes, however, they are prevented from doing so by rags or sticks, which lodge on their seats, and the pump will not work until the obstructions are removed. Easy access is therefore provided to the lower valve, through a hand-hole E, and the removal of the funnel pipe F exposes the upper one D.

Fig. 50.



The connection between this pump and the stuff-chest should be as short as possible, as it is beyond the influence of the agitator, and therefore convenient for the separation and deposit from the pulp, of rags, strings, and foreign matters which may obstruct it. It consists often of a wooden box, about six inches square inside, one end of which is fastened to the bottom, underneath the chest, while the other is connected with the pump by as short a pipe as possible. There must be as many pipes or connections as chests; and whatever material they may be made of, every part of the boxes and pipes must be easily accessible, so that they can be cleaned out at any time.

The supply of pulp should stop, and start, and change its speed with the machine. The stuff-pump must therefore be driven by the same motor as the paper-machine, so that both can work together independently of the rest of the mill.

This simple pump is more convenient than any of the regulators, because the chests may be located high or low, near or at a great distance; it will forward the pulp to the machine without difficulty. Provided that its motion is steady, it cannot fail to furnish the same volume of pulp at all times.

If a patent engine is used, it is supplied by a stuff-pump from a chest; it discharges into another chest, and a second stuff-pump transfers it thence to the machine.

SECTION V.

Paper-Machines.

(A) THE FOURDRINIER PAPER-MACHINE.

95. Historical Sketch and Introductory Remarks.—This chapter has reference to the continuous automatic operation by which the pulp is transformed into dry sheets of paper.

The paper-machine has not, like the steam engine or locomotive, gone forth in a comparatively finished state from the brain of one favored man. It has required the life-long labor of many talented mechanics and manufacturers to change the ancient paper-maker's vat and form into the complicated mechanism, which now, on exactly the same principles, produces millions, where only thousands of pounds could be turned out formerly.

The first patent was taken out for a machine, making endless paper, by Louis Robert, in France, 1799, and he was awarded a prize of 8000 francs by the government. The troubles in which France was involved at that time caused him to go with his model to London, England, where the Messrs. Fourdrinier took hold of it. After spending a fortune and many years of work they succeeded in building a paper-machine which worked tolerably well. In 1807 they stated before Parliament that they had expended £60,000 to overcome the difficulties which they had encountered, and that they did not receive much encouragement from paper manufacturers.

They were never rewarded for their labors in a pecuniary way, and they certainly well deserve to be immortalized in the name of the present Fourdrinier machine.

We do not presume to exhaust this subject in all its bearings, but will try to point out the principles which should govern the construction as well as the management of a paper-machine, and give descriptions which may be of practical value to at least a portion of the readers.

The operations performed under this head may be classed as follows:

I. Regulating and diluting the pulp to its proper state by means of the regulating box, fan-pump, &c.

II. Freeing the stuff from impurities or substances other than single fibres.—This is done by sand-grates and screens or pulp-dressers.

III. Forming the paper.—This is the most important part, and treats of the wire-cloth and its attachments.

IV. Forcing water out by pressure.—The presses.

V. Heating the paper until all the water has been evaporated.—Dryers.

VI. Polishing the surface.—Calenders.

VII. Winding up.—Reels.
VIII. Trimming and cutting.—Cutters.

I. *Regulating and Diluting the Pulp.*

96. Regulating Box.—The regulating box is usually of wood about $1\frac{1}{2}$ by 2 feet, and $1\frac{1}{2}$ to 2 feet high. It is divided by two upright partitions into three compartments, the middle of which receives the pulp, and empties it through copper gates into the two side compartments. One of the latter empties through a 3 to 5 inch copper pipe into the mixing box or into the fan-pump, while the other is connected by a spout with the stuff-chest.

The pump always throws more pulp than is used, in order to make sure of a sufficient supply, and it is the machine-tender's business, to regulate it with the two gates by permitting the surplus to return into the chest.

Every corner of the box in which stuff might lodge, is to be filled up by a board put diagonally across it.

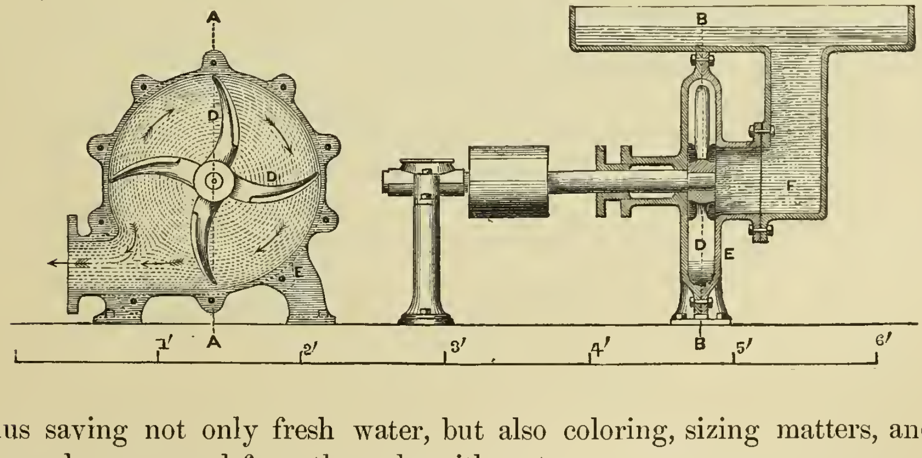
The permanent flow of stuff from the box back into the chest makes it necessary, that it should be located above the top of the latter, and at the same time be easily accessible to the machine-tender.

The machine requires a much more diluted stuff than is furnished by the chest. The pulp is therefore mostly led from the regulating box into a mixing box, where it is thinned out by the addition of fresh water.

A box or save-all gathers the water which leaves the pulp while on the wire-cloth, and empties it into a fan-pump on the driving side of the machine.

97. Fan-Pump and Mixing Box.—The fan-pump, of which Fig. 51 and Fig. 52 are sections through B B and A A, throws the received liquid up into the mixing

Fig. 51. Fig. 52.



box, thus saving not only fresh water, but also coloring, sizing matters, and fibres which may have escaped from the pulp with water.

The arms or wings D on a horizontal shaft revolve fast within a circular casing

E, of the same shape as the fan, so that the whole space will be constantly scoured. The stuff enters through the centre on the side not pierced by the shaft, is pushed forward by the wings into an outlet at the periphery, and can be forced through a pipe to any desired height.

A large cast-iron or metal casing F, extending over the fan-pump and opening into it, receives the water from the save-all.

Instead of using a separate mixing box, the pan F, above the fan-pump, is frequently made large enough to serve in its place. In that case the stuff flows from the regulating box directly into the fan-pump receiver F, where it is diluted with the water from the save-all and a fresh supply from a water-pipe. By this arrangement a separate mixing box is not only saved, but the stuff and water in passing through the fan-pump together are more thoroughly mixed.

The violent beating of the fan-pump sometimes increases the froth on heavily-sized pulp, and a separate mixing box may for this reason be preferred for sized papers.

The speed of the fan-pump must be regulated, so that it will forward all the liquid which is poured into it.

II. *Sand-Tables, Pulp-Dressers, and Apron.*

98. Sand-Tables.—Rags, even if they are carefully sorted, carry with them sand, coal, iron, and other heavy impurities, the weight of which will cause them to separate from the diluted pulp, if it is spread over a sufficiently large surface.

Whenever the paper is found to be sandy, it is a sure indication that the sand-grates in the engines or the sand-tables, or both, are either insufficient or not well attended to.

Any location and form will answer for sand-tables, provided they be large enough, and thereby permit the pulp to flow slowly over them.

If they consisted of only one compartment, the deposits would be carried along to the end of the box, where they would accumulate, and ultimately escape with the pulp. They must therefore be divided into numerous small divisions by means of low gates or weirs. These gates are placed square across the tables in such a way that the deposits cannot be carried over them. Provision must also be made for a quick discharge of these deposits when the tables are to be cleaned out.

The cheapest and most common sand-tables consist of flat wooden boxes with partition boards, which slide in or out between strips fastened to the sides.

A very good table is made of sheet zinc bent up and down, so as to form a succession of bags, like the one shown in Fig. 58. Such zinc tables can be taken out bodily, to be emptied and washed.

From the sand-tables the pulp flows into strainers, and should be spread on them as uniformly as possible.

99. Strainers.—The stuff always contains bundles of fibres which have escaped the

knives of the beaters by lodging in some corner, or strings, which have been formed of separated fibres by the agitator in the stuff-chest or on the passage to the pulp-dresser. Light impurities, such as rubber, wood, paper, or straw, are suspended in the stuff, besides the heavy ones which failed to be deposited in the sand-grates and tables.

Every particle of such matters makes a spot in the paper, and it is therefore very important that they should be kept out.

The pulp-dressers, strainers, or knotters guard the entrance to the paper-machine, and should not let anything pass but well-prepared and separated fibre.

100. Bar-Screens.—One of the oldest screens consists of a brass box, the extended arms of which receive an up and down movement by knockers in the usual way. The bottom of the box is formed of narrow brass bars, shaped like the common grate-bars of a steam-boiler furnace. These bars are pierced by two light brass rods, bearing rings of thin sheet copper or brass between the bars. The thickness of the metal of these rings determines the openings between the bars, and can be varied by means of sets of different sizes. Both ends of the bars fit into cavities in the sides of the screen-box, and form a solid bottom with as many openings or slits as there are bars.

The openings in these screens cannot be made narrow or fine enough for the better grades of paper, and, if they are taken apart, it is very difficult to put them together again in such a manner that the distance between the bars will be everywhere the same. The slightest increase of width between two bars allows the knots to pass and makes the screen useless. These strainers, though costly, are very substantial, require no renewal of plates, and answer very well for lower grades of paper or a preliminary screening.

101. Plate-Screens.—The screens most generally used consist of brass or composition plates, about 10 by 30 inches, and $\frac{3}{16}$ to $\frac{3}{8}$ inch thick, with narrow parallel openings cut into them by a machine in such a way that they are finest on the upper side, which carries the pulp, and widen out gradually below. The pulp, which has once passed the fine openings on top, thus flows freely through the constantly enlarging channels.

The passage of pulp through the slits wears off the metal and widens the openings. To avoid frequent renewals, the hardest possible composition, which has yet elasticity enough to bear the constant knocks without breaking, should be used for these plates.

A pulp-dresser of this kind is shown by a section and plan in Figs. 53 and 54, and by a perspective view in Fig. 55.

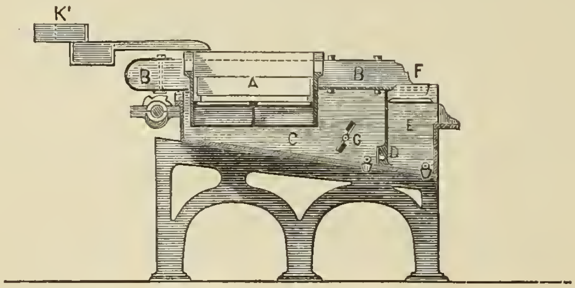
The screen A, the sides of which extend several inches below the plates, is fastened to levers or arms B, and suspended in a vat C. The pulp in the vat C must be kept at such a height that, while the lower edges of the screen are constantly immersed, an empty space remains between the screen-plates and the surface of the stuff.

The vat C is full of pulp before the wire starts, but as soon as the outlet gate D

is opened, the level falls to the desired point—perhaps as low as the overflow lip E, but at all events somewhat below the plates—creating a vacuum between itself and the pulp in the screen. This vacuum is of great assistance in forcing the pulp through, and must be carefully preserved.

If the stuff in the vat is allowed to accumulate till it rises above the screen-plates, the fibres remain suspended above them and will pass with difficulty through the openings; and if the supply of pulp in the vat is reduced so that its surface sinks

FIG. 53.



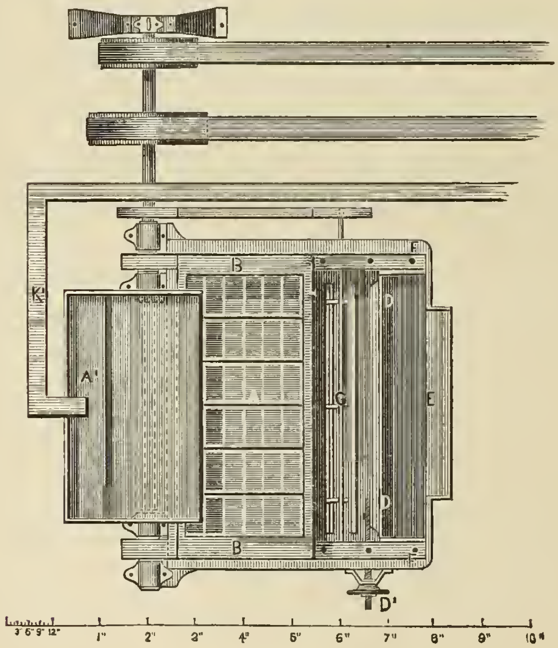


FIG. 54.

beneath the lower edges of the screen-frames, the air enters the empty space, or vacuum, below the plates, and the suction, with which the latter assists the passage of the pulp, is lost.

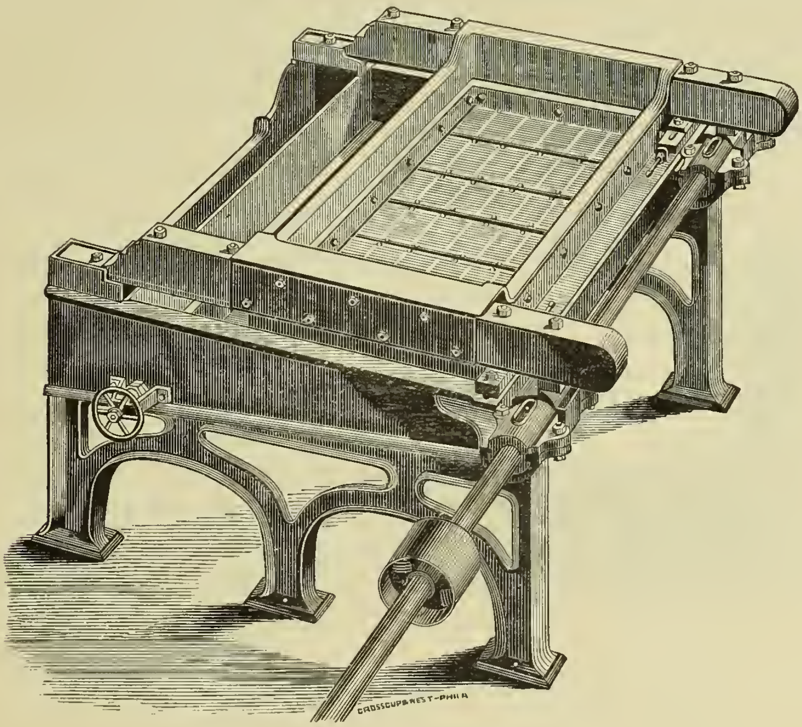
The gate D must therefore be constructed so that the flow of pulp can be easily regulated by it, and at the same time evenly distributed over the whole wire-cloth. The one indicated by D consists of a stationary brass plate, with a number of round

holes, at equal distances, extending all across the front side, and of another identical but movable plate, which slides to and fro on the former, as directed by the hand-wheel and screw D[1] outside of the vat. The largest possible opening is obtained when the holes in both plates cover each other; and, by moving the sliding plate, it can be decreased or closed, as may be desired.

Some kinds of stuff are so *free*, that the water escapes quickly through the slits, and leaves the fibres on the screen. Whenever this is the case, the liquid in the vat C must be, contrary to our general rule, kept as high as the plates, so that the fibres are held afloat until they pass through the openings.

The vat should not be larger than is necessary to give room to the screen; any

Fig. 55.



additional space is an evil, as it furnishes an opportunity to some of the fibres to separate and lodge on the bottom, unless an agitator G, consisting of two wooden paddles, and driven by belt and pulley outside, is used to keep them afloat.

The bearings of the knocker-shaft and screen-arms are frequently fastened to the vat, and communicate to it the knocks and vibrations of the screen. If such vats are of wood, they must soon become leaky, and remain a source of trouble in spite of lining and calking.

Cast-iron vats are not open to this objection; they carry the shafts with safety, and, though more expensive, will be found cheaper in the end, if the pulp lost through wooden ones is taken into consideration. The vat represented in our drawings consists of one solid piece of casting.

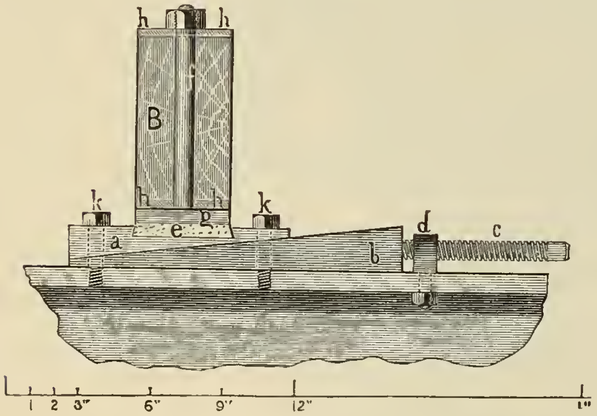
The knocker-wheels are exposed to much wear and tear, and should always be chilled. A chilled-iron knocker-wheel outlasts many common soft iron ones.

The cast-iron frames, which carry the vat, must be bolted on a very solid foundation. If they stand loosely, the power, which is intended to shake the screens, will vent itself on the whole structure, and the motion of the screens is lessened in the same proportion.

Wooden screen-frames wear out and render frequent repairs necessary, while iron or brass ones give little or no trouble. The frame of our screen A is one piece of cast iron. The brass screen-plates are fastened to it with bolts, and held down on the ends by strips of wood, bolted to the sides.

The arms B carrying the screen should be either of hammered iron or wood, as cast iron ones would have to be made very heavy to stand the continuous knocks for a long time without breaking. A strong, sound piece of wood, well fitted and bolted to the screen-frames, will deaden the noise of the knockers, and is therefore preferable to metal. The arms B in Figs. 53, 54, and 55, are of wood, but have, as shown in the detailed section, Fig. 56, an iron spring *h*, $\frac{3}{4}$ inch thick, bolted to them and covering the lower side and the round end near the knockers. (Fig. 53.) This spring is longer than the wooden arm, and the free projecting end is fastened to the iron vat, at the farthest end, with a single bolt F. The free end of the spring is elastic enough to allow the screen to make the short up and down movement given to it by the knockers, and is an improvement on the shaft and bearings usually found in its place.

Fig. 56.



The parts of the screen nearest to the knockers are lifted higher than the more distant ones; and the difference is the greater the shorter the arms B, or the nearer the turning-points F are to the screen. The motion of the screen in all its parts should be as uniform as possible, and this will be accomplished by long arms, the turning-points of which are as far from the screen-plates as possible.

It is important to avoid vibration in any part of this apparatus, because the motion of the screens, as said before, will be reduced by exactly the amount absorbed by other parts. The shafts should therefore be strong and heavy, supported by long bearings on both sides of the knockers, of wrought iron and not less than $2\frac{1}{2}$ to 3 inches diameter.

The extent of the up and down movement can be regulated by the depth to which the screen-arms B are allowed to drop after having been raised up by one of

the knocker-cams. It is commonly done by numerous strips of leather, which are fastened on the rim of the vat, beneath the levers. Strips of different thicknesses must be kept on hand to form cushions of any desired height; they must be frequently renewed, and generally require a great deal of attention.

Fig. 56 represents an improved cushion, consisting of two flat keys *a* and *b*, which form a parallelogram by uniting on the diagonal. The key *a* is stationary, but *b* can be pushed forward by means of the screw *c* and the immovable nut *d*, and thus raises *a*, which is prevented by the bolts *k k* from moving sideways. If it is desired to lower the cushion, the screw *c* is simply turned backward and the key *b* pushed after it. A piece of leather *e* is dovetailed into the upper key *a*, and receives the falling arm B to prevent noise.

A bolt *f*, passing through the arm B and spring *h*, has a steel plate *g* fastened to its end, which drops on the leather *e*, and can easily be renewed when worn out.

Iron screens are too heavy to be lifted up by hand, but they can easily be raised and held in any position with differential or ordinary pulley-blocks, or with any other simple lifting arrangement.

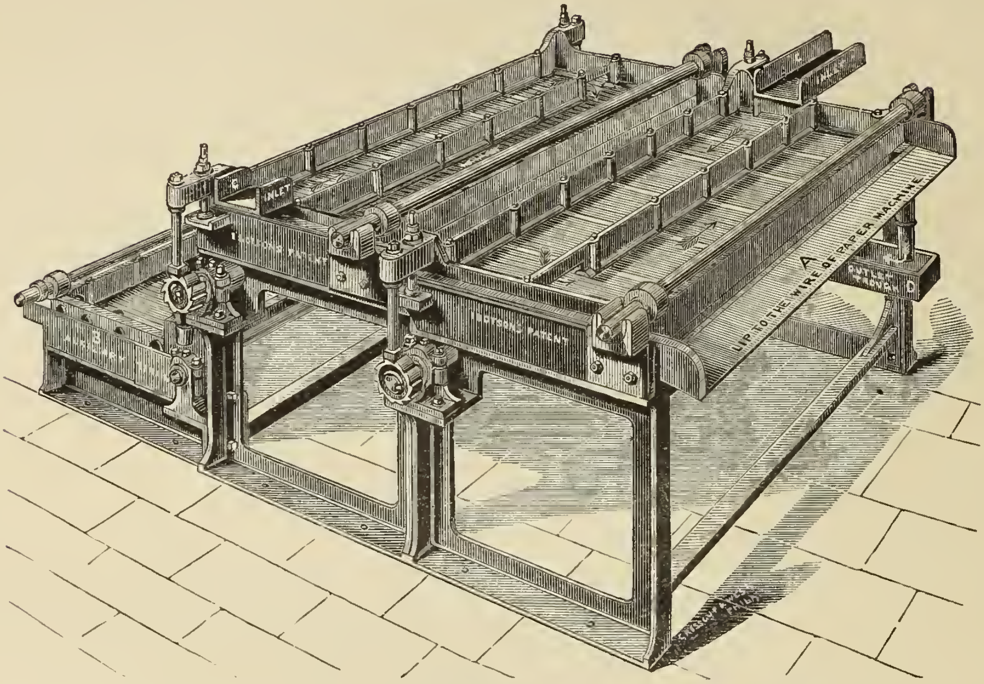
The principal faults of this system of strainers are, that the knots remain on them, settle in the slits, and prevent the passage of the pulp. The knots must therefore be frequently removed by the machine-tender, who scrapes them together into a corner, and takes them out from there. However carefully this may be done, some of the smaller knots will be forced through by the scraping motion; and by the removal of all obstructions a larger amount of fibres is enabled to pass through the screens, after they have been cleaned, than before. We therefore find the paper to contain more impurities and to be heavier, immediately after the screens have been cleaned than at other times. Some of the knots which have been pushed through on that occasion may not enter into the paper until a considerable time afterward, and will then show themselves as spots, or even cause breaks.

102. Ibotson's Strainer.—W. Ibotson has invented a combination of strainers, by which these difficulties are overcome.

The following Fig. 57 represents one of these strainers, with two screens and one auxiliary one.

The pulp enters the screens through the two inlets C, and flows over the plates in the direction indicated by the arrows, thus passing over every part of them. Both screens are put in motion by knockers in the usual way, and the pulp which passes through the slits, proceeds over the lip A directly to the wire of the paper-machine. All of that portion of the pulp which could not pass through the slits descends at the end of the course, through an outlet-trough D, into the auxiliary strainer B. The stuff, which makes its way through the plates of this strainer B is pumped back again into the upper screens, and the knots and impurities remaining on it, are taken out by hand in the ordinary manner.

Fig. 57.



The following Figs. 58 and 59 show in front-elevation and plan the connections of an Ibotson strainer, with the feed and discharge spouts:

Fig. 58.

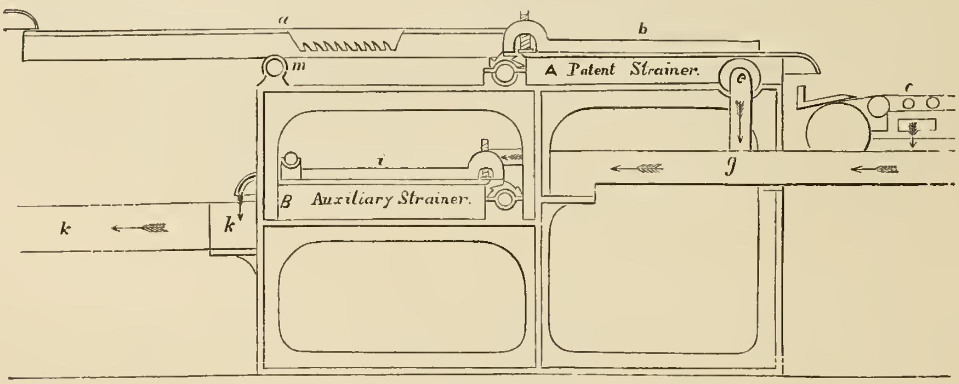
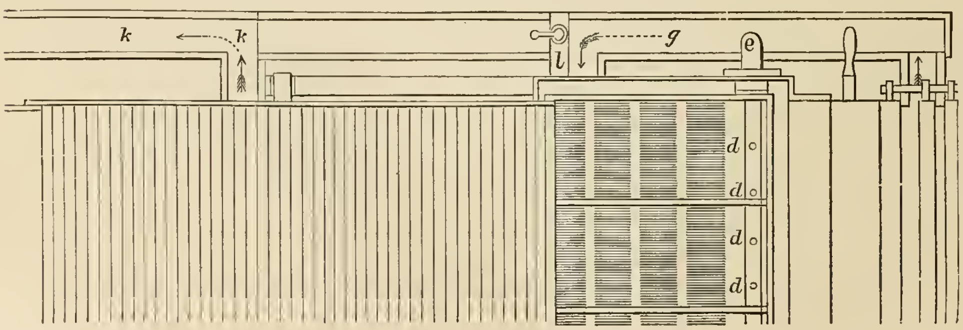


Fig. 59.



The stuff is admitted from the sand-catcher *a* along the front of the screen *b*; the bulk passes through the plates of this screen *b* to the wire *c*, while a small portion, containing all the dirt and knots, flows over the plates and through the holes *d d d*, Fig. 59, into a trough underneath. At each end of this trough are pipes which pass through water-tight glands in the side of the vat, forming at once the supports for the strainer and means of exit for the stuff. Having passed through these pipes the stuff descends by vertical pipes *e e* into the shoots *g g*. These shoots also receive the backwater from under the wire, and thus diluted the stuff passes into the auxiliary screen *i*. There the dirt and knots are retained, while the good fibre passes through with the backwater, is conveyed to the lifter by the shoot *k*, and returned to the strainer *b*.

In order to facilitate the cleaning of the auxiliary strainer *i*, the valve *l* is provided, through which, if opened, the stuff is allowed for the time, to pass directly from shoots *g g* to shoot *k* and the lifter or stuff-pump; the strainer *i* is thus laid dry, and can be thoroughly cleaned without in any way affecting the quality or quantity of stuff passing to the wire. The sand-catcher *a* is made to rest on a pivot *m*, and can be turned up into a nearly vertical position. This greatly facilitates cleaning it, and permits the two strainers to be turned up also.

When space is wanted, the auxiliary strainer can be placed under the patent strainer, and two patent strainers can be placed in one vat if required.

A large number of these strainers are in operation in England and France, and seem to give satisfaction. They can hardly fail to make the paper more uniform, as the principal strainers are never touched by the machine-tender, and the pulp passing through the auxiliary one is not allowed to go directly to the machine. As no knots remain on the plates, to block up the slits, their efficiency is increased, and the openings can be made narrower.

103. Suction Strainers.—In some mills pulp-dressers are used, which act entirely by suction without vibration.

The screens are stationary, and form a perfect diaphragm across the vat, so that nothing can pass in anywhere, except through the openings in the plates. The bottom of the vat consists of a rubber-lined plate, which is moved up and down by means of levers. Its action is exactly like that of a pump, and it forces the pulp through the openings by suction only.

The continued motion soon wears out the rubber-joints, and causes frequent and costly renewals.

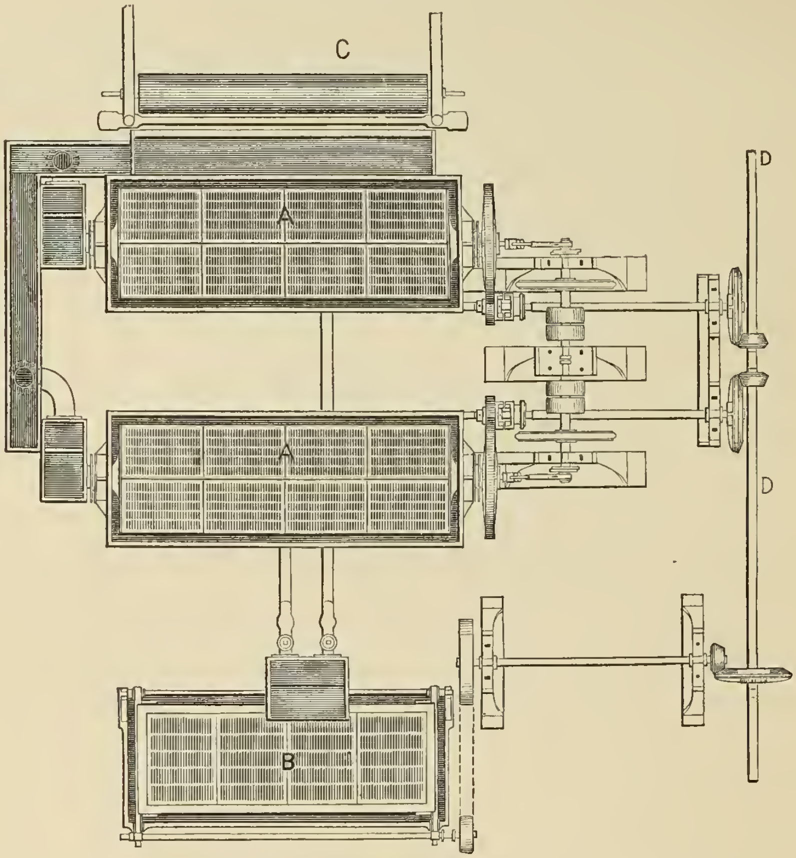
Screens of this kind, working by suction only, cannot be efficient for any but the finest and best prepared pulp, or such as has previously passed another screen, as the knots are not prevented from settling in the slits, and may obstruct the passage of the pulp.

104. Revolving Screens.—Many revolving screens have been constructed and again abandoned, but those represented by a plan in Fig. 60, built by George Bertram, in Edinburgh, seem to have found favor with paper-makers in England and Scotland.

The two strainers A A revolve in vats filled with pulp, impelled by the gearing shown in the plan, and their four sides are covered with ordinary screen-plates.

Their interior is provided with a rubber suction arrangement or bellows, moved from the centre, like the piston of a pump; the pulp is thus drawn in from the out-

Fig. 60.



side through the slits of the plates, and discharged into the troughs, which conduct it to the wire of the machine.

The knots, which were unable to pass through the openings, remain in the vats, and would soon fill them up, so that the strainers would have to be stopped for the purpose of cleaning them, if they could not be drawn off into the auxiliary screen B, which is of ordinary construction.

105. Reversed Screens, in which the stuff passes through the plates from below, are sometimes used to give a last cleaning to pulp, which has previously passed other pulp-dressers. The knots and other heavy parts fall to the bottom instead of adhering to the plates and obstructing them; but if there should be too many impurities, the vat would have to be cleaned out so often, that the loss of time and pulp would become of more importance than the usefulness of the screens in improving the quality of the paper.

106. Disposition, Size, and Management of Strainers.—Mr. Planche recommends the use of three different strainers in the following order:

1st. A strainer of the ordinary vibrating kind.

2d. A pulp-dresser worked by means of a suction plate.

3d. A strainer in which the pulp passes through the plates from below.

The first one of these screens has the widest openings and retains the coarsest impurities, while each succeeding one is cut finer, and keeps out knots which have passed through the preceding ones.

It is a subject of controversy whether the stuff will be better cleaned by such a succession of screens than in passing only once through finely-cut plates, of which there are enough provided to permit of its being spread over a large surface.

The danger that the knots, which may pass through some faulty or worn-out opening, may reach the wire-cloth and enter into the paper, is certainly greater in the latter case, but the former system is more complicated.

The plates may be cut finer as their number is increased.

Fine papers are usually made of the best kind of stock, well prepared, before it is admitted to the machine, and passing through the screen-plates without difficulty.

But the pulp-dressers are of the greatest importance for medium qualities of paper, and the large and fast-running machines, used at present, should never be provided with less than two screens of 15 to 20 square feet surface each, which may act as one.

The addition of a second strainer of different construction, to correct the faults of the first set, would in most cases be repaid by an improvement in the quality of the paper.

It is the machine-tender's duty to regulate the speed and vibrations of the screens, as well as to remove the thick stuff and impurities on the plates of ordinary pulp-dressers. If this is not done, the passage of the stuff will be obstructed, and it must run over the top. The screenings should be taken out at regular intervals, and without hammering or knocking the plates, because any such rough action would defeat the object of the pulp-dresser, and force through the openings those knots and impurities, which are to be kept out.

The frequent examination of the screenings is to the foreman a guide for the improvement of all preceding operations. If too much rubber, sealing-wax, and similar substances are found, it is an evidence that the rags or waste papers have not been sorted as carefully as they should have been. If lumps of fibres, rags or paper are found, the engineer is to blame for not stirring the pulp often enough, or for allowing it to leave the beater without having been thoroughly brushed.

The screenings may be gathered and used for some of the lowest grades of paper, such as coarse wrapping, match-box, roofing, &c.

107. Connection of the Screen-Vat with the Apron.—It is necessary to have a gate or valve between the pulp-dresser and the wire, by which the flow of pulp can be

suddenly stopped or started at will. In the vat represented by Figs. 53, 54, and 55, this is done by means of the sliding gate D, but in many cases it is desirable to have a passage-way between the screens and the wire, through which the machine-tender may go to the driving side of the machine.

In that case the pulp-dresser vats are made as narrow as possible, and a square chest A, represented in Fig. 61, receives the pulp which has passed through the screens. It is usually of wood, the bottom at least one foot above ground and the top level with the top of the pulp-dresser vat.

A copper or cast-iron pipe, about 6 inches wide, connects the bottom of the pulp-dresser vats with that of the chest A. (See Plate IV.) This pipe is placed on the floor, bridged by a bench between the chest A and the screens, and supplied with a stop-cock, through which the vats and chest A can be emptied and cleaned. The stuff in A is prevented from settling by an agitator, one end of which is fastened with the screw B. The upper corner, nearest to the wire, is divided off from the rest by the partitions C C; and a valve D—or better, a sliding gate, such as described before—on its horizontal part, admits the pulp to the wire. An opening E, as wide as the wire and about 4 to 6 inches high, is cut out in the front side of the chest A, the lower edge of which is about 3 to 4 inches above the apron.

Sometimes it is necessary to close the valve D, and stop the flow of pulp to the wire so suddenly, that the machine-tender has not time first to turn off the pulp by means of the gates in the regulating box. It then accumulates in the chest A, finally runs over, and is lost. To prevent this, an overflow spout connects the upper part of A with the stuff-chest, and furnishes an outlet for the surplus pulp.

The stuff in leaving the screen-plates, sometimes hangs on to their lower edges, and forms long strings of fibres, well known to paper-makers, which either break the paper or make a dirty spot. To catch these strings we recommend the insertion of a wooden frame, with thin upright wooden slats, about 2 to 3 inches apart, similar to the rack of a water-wheel, into the opening E from inside the chest A. It can be fastened by a few washers, and removed if desired. The strings will hang on to the upright slats with remarkable tenacity, and can be taken from them at any time.

A sheet of copper or brass, forming an outlet or lip, is fastened to the lower edge of the opening E, and over it the pulp flows on to the apron.

108. **Aprons.**—To support the apron, brackets are fastened to the posts G which carry the breast-roll. A solid brass plate, not flat as H in Fig. 61, but bordered by a flange about 2 inches high all around except on the side against the wire, is usually bolted to these brackets. The open gap between this plate and the wire is bridged over by a piece of leather or oil-cloth, one end of which is fastened to the edge of the plate by means of screws, while the other end rests on the moving wire. It must reach far enough to lay flat on the wire, and it is turned up on the sides to prevent the pulp from escaping in that direction.

If oil-cloth is used, a strong piece of canvas must be placed under it, as otherwise the friction of the wire on the end which rests there would soon tear it. This

constant friction wears out even the best aprons, and makes frequent renewals necessary.

Whenever the width of the sheet is to be changed, the turned-up sides must be undone, shifted, and readjusted at the proper places.

To avoid this trouble and loss of time, Mr. Thomas Lindsay has constructed the *patent apron* represented in Fig. 61.

Instead of leather or cloth, it consists of a brass centre-plate I and two side-plates K K, which can be made to slide over I until they meet in the middle. This is done by means of the worms and worm-wheels M and the two screws L, which are cut right and left handed. They are not open as represented in the drawing, but

Fig. 61.

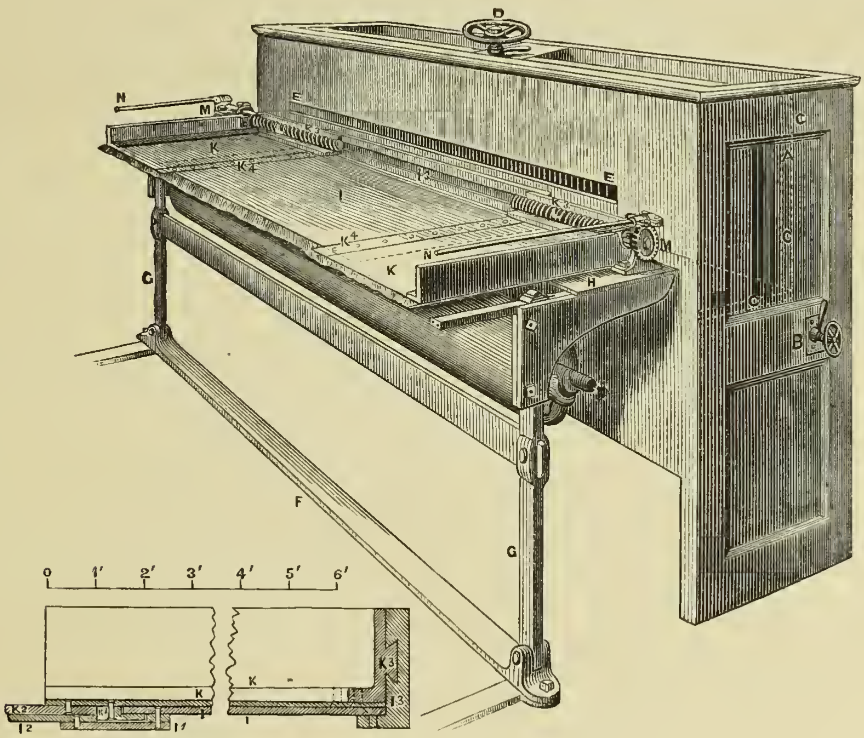


Fig. 62.

covered by hollow brass tubes, which protect them from the pulp. The rods N, carrying the worms, are a continuation of those Y in Fig. 1 and Fig. 2 of Plate I, which move the deckels; the apron and deckels are thus moved in and out together by turning the cranks Y^1 (Plate I), and this can be done while the machine is running or at rest. To prevent the escape of stuff through the joints between the plates K K and I, strips of brass K^4 K^4 are screwed on K K, and project over I. Strips of leather, fully as thick as K, are fastened to the lower side of the projecting part of K^4, and make a tight joint.

Fig. 62 represents a section, in the direction in which the pulp flows, through

that part of the apron, where one of the plates K covers plate I. The slide K^3 forming part of the end-plate K is dovetailed into the stationary frame I^3, and narrow brass sheets K^1 are riveted to the plates K for the purpose of keeping both plates K and I immutably joined together at the forward edge while they slide sideways. The brass sheet I^1, riveted to the plate I, has a piece of leather I^2 riveted to it all along its front edge, and like pieces of leather K^2 are riveted to plate K. The unavoidable short gap, between the apron and the wire, is closed by these short pieces of leather I^2 and K^2, which reach nearly to the gates or sluices.

III. *The Wire-Cloth and its Attachments.*

109. Qualities and Position of the Wire-Cloth.—The wire is the part of the machine on which the paper is made; it represents the "Form" of the paper-makers of old. It is woven on a loom similar to those used for cotton and linen goods, on which brass wire is substituted for yarn. When the required length of cloth is finished, it is taken from the loom and the ends are sewed together by hand, so that it will form an endless wire-cloth.

The qualities which constitute a good wire-cloth are:

That it is uniformly woven, or that the threads are parallel with, and at equal distances from, each other;

That the wire thread be tough, pliable, equally thick in every part, and capable of suffering a strong tension without tearing apart or breaking. The comparative strength of the wire threads can easily be tested by trying how much weight can be held suspended by pieces of the same length without breaking;

That the seam should be made with great care, so that it will neither make too distinct a mark on the paper, nor break any sooner than the cloth itself.

Annealed wires are softer and more pliable than ordinary ones, and it is claimed that they will last longer under the same circumstances.

The number of a wire-cloth represents the number of threads contained in one inch of its length; No. 60, the number most used, contains 60 threads in 1 inch. The finer qualities of paper, such as book or letter, are mostly made on No. 70, with 70 threads in 1 inch. As a rule, the higher numbers are used for fine, and the lower ones for coarse paper.

A good supply of wires should be always kept on hand at the mills, as suitable ones cannot always be found in stock at the stores.

The wire-cloth is spread out flat horizontally, for the reception of the pulp and the formation of the paper, and at the same time moves rapidly forward.

Fig. 1, Plate I, is a partial plan, and Fig. 2 the front elevation of the wire part of an 86 inch machine, which has been built by Messrs. Pusey, Jones & Co., Wilmington, Del., for Messrs. Jessup & Moore's Rockland Mill.

The following plates, II, III, and IV, and the previous and following figures, 61, 71, 72, 79, and 80, represent parts of the same machine.

It is supported in this position by the breast-roll A, a number of small rolls B B B, consisting of brass or copper tubes with steel journals, and by the couch-roll C. The shaft of this couch-roll carries a pulley C″, by which it is put in motion; and with it moves the wire-cloth, which on its part turns by friction all the carrying-rolls over which it passes. On the return trip from C to A, the empty wire is supported by the rolls D D D′, the latter one of which also regulates its tension. If one or more of the carrying-rolls are not exactly parallel and level with the rest, or if the wire-cloth is a trifle longer on one side, it receives a tendency to shift sideways; and to correct this, one of the tube-rolls, usually B′, somewhat larger than the others, can be moved back and forward by a screw and hand-wheel B″ on the front side of the machine, until the wire keeps the middle between the frames.

These frames, fastened to sills on each side, are identical, and carry all the wire-rolls. Their upper part consists of a strong steel, iron, or brass bar E, to which the bearings of all the rolls B are secured. A large number of these rolls, which lay very close together, have common supports E′, fastened to the bars E with brackets E″, but the others rest in separate brass hangers. One end of each bar E is fastened to the cast-iron frame H by means of a screw-bolt H′, which holds it without preventing it from turning slightly. The cast-iron post F which supports the other end, can be moved sideways, swinging on a bolt or hinge at the bottom, which holds it in position while the top is subjected to a shaking motion. Three brass columns G, G, and G′, support the bar E; they rest on pivots, which permit them to follow the lateral motion of the frame, and their upper ends are turned down to narrow journals, which fit cavities in the bar E. To remove these columns G and G′ the bar E is simply sprung up enough to clear the projecting narrow journals. The bearings A′ of the breast-roll A are attached to the cast-iron posts F, and the columns G and G′ are supplied with sleeves and boxes G″, fastened with set-screws, by means of which the stretch-rolls D and D′ can be set higher or lower. It is sometimes necessary to move some of these rolls so little, that some means must be provided to adjust them very accurately. The bearings of the breast-roll and the principal stretch-roll D are therefore supplied with screws A″ and D″ on both sides of the machine, by means of which the most minute changes can be made in their positions.

It is very important that all the rolls, especially the large ones, should be strong enough to endure without springing the heavy pressure to which they are sometimes subjected by a tightly-stretched wire.

It is the tendency of our time to increase constantly the width and speed of the machines, and yet we find these large and fast machines sometimes furnished with rolls and shafts of the same diameter as those for slow and narrow ones. If the rolls are not strong and stiff enough they will bend; the wire will be stretched more in one place than another, causing it to run unevenly and wear out fast. Copper or brass stretch-rolls D D^1, of five inches diameter, may be sufficiently strong for a 62-inch wire, while they should not be of less than 7 or 8 inches diameter for an 86-inch wire.

110. The Couch-Rolls especially should have a copper casing of not less than $\frac{5}{16}$

or $\frac{3}{8}$ inch thickness, and a diameter of from 12 to 15 inches for wide machines, supported inside by many iron spiders on a strong iron shaft.

Hand-made paper was taken from the mould, and stretched out on a felt by a clever movement, and the workman who performed this part of the operation was called the "coucher." The couch-rolls C and C′, between which the paper passes after it has been formed on the wire, are intended to do his work and press out water besides.

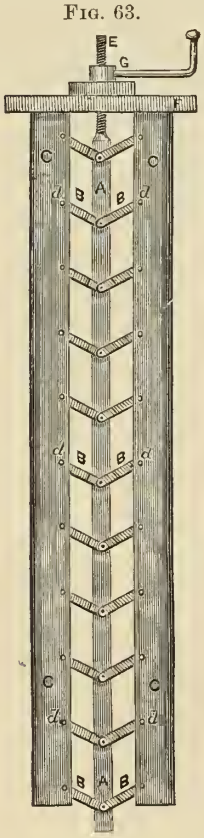
They are for this purpose mostly covered with wool jackets or endless pipe-shaped web, which, to fit close, is used of rather small size, and expanded by a stretcher to the proper width.

Two wooden keys, forming a parallelogram by joining on the diagonal, are often driven and hammered into the jackets, and left there until they are sufficiently widened.

A more convenient stretcher is represented by a plan, Fig. 63, and a section Fig. 64.

A flat iron bar A, several feet longer than the couch-rolls, has fastened to it with pins a number of arms B, which carry on their other extremities two pieces of wood C C, also longer than the rolls, about 4 inches thick, and well rounded where they receive the jackets. The arms B are fastened with pins *d d d* in such a way in C C that nothing projects on the flat sides of the wood to touch the woollen cloth. The flat iron terminates in a screw E, and when the jacket is put over the stretcher, the knot G is screwed down on a wooden cross-piece F, which presses on the keys C C and opens them out. Care must be taken in the construction of this stretcher to make and fasten the arms B exactly alike, so that the keys C C will have parallel outsides in any position.

Fig. 63.



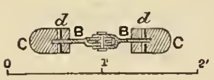


Fig. 64.

The jackets are soaked in hot water before being put on the stretcher, and are left there until they are perfectly dry, or, what is better, until they are used, as they cannot then shrink if they should happen to get wet or damp.

A jacket thus extended is easily drawn over the couch-rolls, its ends are sewed together with strong twine, and cold water is thrown on it until it shrinks tight on the roll. The jackets can be and are frequently shrunk on the couchers with hot water; but they are softened thereby, and will not preserve their straight lines across so well, nor last so long, as if treated with cold water.

Some air will remain under the jackets while they are being put on, and to give it an opportunity to escape, a number of small holes must be drilled in the shell of the couch-rolls.

The jackets are very expensive and troublesome, and to do away with them, rolls covered with soft vulcanized rubber, have been put in their place.

Messrs. Curtis & Bro., at Newark, Delaware, have used for the last one and

a half years an old iron press-roll covered with soft rubber, in place of the usual lower copper couch-roll, and they are very well satisfied with it.

Iron or any other kind of metal rolls will answer if they are thus covered, and the invention may be, and has been applied to all the carrying-rolls. The soft rubber covers will not only save the labor and money spent for jackets, but the reduction of the friction on the rolls will give a longer lease of life to every wire-cloth.

The patent for this invention is owned by Mr. W. W. Harding, publisher of the *Inquirer* at Philadelphia, Penna.

The upper couch-roll C′ is connected to levers and weights on both ends, which increase its pressure on the paper.

Instead of the ordinary single lever, our drawing represents a "compound lever." The rod I″, which is hooked to the frame of the upper coucher, is fastened to the first lever I′ by means of a nut. This lever I′ rests in the hanger I^4, and the second lever I turns in the bracket-bearing I^5, near which it is connected with the first lever I′ by a pin I^6. The weight I^3 can be shifted to any point of the lever I, thus increasing or decreasing the pressure, and accomplishing as much as the heavy cumbrous weights usually seen on the long single levers. These compound levers will give perfect satisfaction as long as they turn freely on the connecting pin I^6, which should be kept well greased or lined with brass, to prevent rusting.

It is of importance that the upper couch-roll should be put on the lower one exactly parallel, after a new wire has been put on the machine. In fact, all the rolls must be parallel, or the wire will not run well; but if the upper couch-roll is out of its true line, the wire will become twisted and run in wrinkles, or stretch unevenly, and spoil in a very short time. The journals of the couch-roll C′, as shown in our drawing, run in boxes fastened to levers M, supported by and turning on pivots or studs, so that the roll can be lifted off and on quickly, and without changing its parallel position, by simply turning these levers M up or down.

The action of the suction-boxes in addition to their weight causes the ultramarine to settle to the lower side of the paper, and to counteract this influence the upper coucher has been pierced with numerous holes, and connected with a pump which draws the air out of it, thus creating suction on the upper side; but we have not been able to learn anything about the practical working of this plan.

The lower coucher is driven by a pulley C″ on shaft K^2, and can be put in and out of motion by the coupling K and lever K′.

The lever K′, which stands upright, while the wire is in motion, disconnects the coupling if simply pulled backward. A very ingenious device is used to hold the lever in its upright position, but as it is also applied to the presses, and more distinctly shown on Plate II, and explained on the corresponding pages, we refer to them. An arrangement, by which the coupling can be thrown in or out from the driving side, could be constructed much simpler, but it would not answer the purpose so well, because the machine-tender, whose place is at the front side, should be able to stop the wire quickly in case of accident.

A copper sprinkling-pipe L, across the upper coucher, gives it a constant washing, the water of which is prevented from going around the roll by the guard-board L″ and the little copper roll L′. The guard-board L″ is made of a three-inch plank of good tough wood, cut to fit the roll, and its narrow edge is covered with double thick felting, tacked to the sides, which can be renewed when necessary. It is bolted to iron frames M′ on each side, which form part of the movable levers M, and thus held down on the roll C′, whether the latter is in working position or raised up.

The paper breaks frequently, for the simple reason that this guard-board is not well fitted to the roll, and the water consequently runs through on the web in some place, making it more wet and tender there than anywhere else. Though the break may occur on the presses, or even at the calenders, it can often be traced back to this cause.

At other times the paper is crushed between the couchers, and breaks in consequence, or retains a cloudy appearance. This indicates that the pulp has not been well enough formed into paper; that it carries too much water, and is too soft to withstand the pressure of the upper coucher. It may be so from imperfect working of the suction-boxes or from too great a dilution of the pulp. The remedy in this case is to restore a good suction, mix the pulp with less water, or reduce the shaking motion. If very heavy paper is to be made, and the stuff has not been beaten as short as it should be, the side which rests on the wire, may be formed into a web too quickly, prevent the escape of water from the pulp above it, and the paper must become crushed and cloudy. Stuff of this character should be worked into lighter paper.

111. Tube-Rolls.—It is evidently of importance that we should be enabled to draw as much water as possible from the web while it is on the wire. If we observe the discharge of water through a wire-cloth, we find that more water leaves where it is supported by one of the tube-rolls B B, or at the points of contact, than in the open spaces. This is probably due to the stream which constantly flows over the surface of these rolls, connecting with the pulp on the wire, and thus drawing the water from it by contact or capillary attraction, while its weight alone has to force it away where there are no rolls.

It is therefore advisable to use a great number of tube-rolls.

112. Suction-Boxes.—Much water is also extracted by the suction-boxes. They are water-tight boxes N N made of wood or metal, which have no communication with the air except through the wire which is passing over them. The water is drawn from these boxes by suction, produced in the oldest machines by bell-shaped air-pumps. At the present time syphons or suction-pumps are used for that purpose.

The pipes N′ are fastened to the bottom of the boxes N; descend as deep as can conveniently be done, say from 10 to 18 feet, and are provided with a valve or stop-cock as low down as feasible. The box N and pipe N′ are kept full of water all the time, and when the wire has been started and the pulp is spread on it, the machine-tender opens the cock, the water runs out, creates a vacuum underneath the wire; the

atmospheric pressure on top forces the water out of the pulp, and keeps up the stream, which escapes through the pipe. To understand the action of this syphon thoroughly we shall examine the pressure exercised by the atmosphere in a given case.

The pressure of an atmosphere, as shown by the barometer, is equal to that of a column of quicksilver of from 26 to 29 inches height, or (quicksilver being fourteen times as heavy as water) of a column of water $14 \times 26 = 364$ inches $= 30\frac{1}{3}$ feet high.

The pressure, with which water is forced from the pulp, is equal to that of the atmosphere, less the resistance offered on the lower side. If the wire-cloth fits air-tight on the box, and the syphon-pipe descends, for example, 18 feet, the air can offer resistance on the lower side only through this column of 18 feet of water, and will be reduced to 30 less $18 = 12$ feet. The water is therefore forced from the paper with a pressure of 30 less $12 = 18$ feet, or with $\frac{18}{30} = \frac{3}{5}$ of an atmosphere.

The pressure of the atmosphere is also equal to 15 pounds on every square inch of surface, and the suction which draws the water from the paper is therefore, for our example, $\frac{3}{5}$ of 15 pounds, or 9 pounds for every square inch of open suction-box covered by the web. The pressure on a sheet of 60 inches width on an uncovered box of 6 inches inside width would amount to $6 \times 60 \times 9 = 3240$ pounds.

The pressure is, as we have shown, always equal to that of the column of water in the pipe; the longer the vertical height of the syphon, the stronger the suction. It is, however, limited to the pressure of the atmosphere, or less than 30 feet.

If the vertical depth of the syphon-pipe would be over 30 feet, it could not be balanced by the atmospheric pressure, and would remain empty and useless.

The quantity of water drawn away by the suction-boxes can in a measure be regulated by the valve or stop-cock. If the pipe be too large and fully opened, more water will escape than can be replaced from the pulp, air enters, and the suction is at an end until the syphon is refilled and started again. Whenever the paper breaks, or if from any other cause air finds access through the wire, or if the pulp furnishes an insufficient quantity of water to fill the pipes, the syphon-pipes run empty and must be primed again.

In many mills the paper-machine is so little elevated above the tail-race that a strong suction by syphons cannot be obtained, and then the artificial suction of pumps must be resorted to. They work as long as they are moving, require no attention, and are often preferred even where long syphon-pipes could be used. It is true that they consume power, but they can also be made to throw the liquid, which escapes through the boxes, back into the mixing-box, and thus effect a saving which may compensate for the power. The suction of a syphon-pipe is limited by its height, while the speed of the pumps, and with it the quantity of water withdrawn, may be increased or decreased, as desired.

Any good suction-pump answers for this purpose, but a pair of double-acting piston-pumps, driven by cranks placed at right angles on the same shaft, keep up a continual stream, and are used in many mills.

We have also seen the suction produced by a roughly constructed apparatus,

which works on the same principle as Giffard's well-known boiler-injector, but consider the live steam consumed in it more expensive and less reliable than pumps.

If the boxes are not covered, the wire-cloth is bent in by the heavy pressure on it, and the strong friction on the corners cannot fail to injure it in the course of time. Perforated metal plates have been and are used to prevent this, but those made of hard rubber $\frac{1}{4}$ to $\frac{3}{8}$ inch thick are now generally preferred. They have as many holes as can be drilled into them without weakening the plate. If these holes are made funnel-shaped, with the wide side on top, they will fill up with the fibres, slime, and clay from the paper, and soon become useless; they should be either straight through, or rather a little wider below, to make sure that they will not be obstructed. A patent has lately been taken out for glass plates, which would not only be hard, but permit the inside of the boxes to be seen while the sliding heads are adjusted.

A slide at each end of the box can be moved farther in and out by a brass screw and hand-wheel N^2, to suit any width of paper. The space between the slide and the end of the box would facilitate the admittance of air below the web of paper, if it were not filled with water; a small stream is therefore constantly pouring into it through the pipe N^3.

If very wide paper is made and the slides are near the ends, the screws moving them project considerably outside of the box and form an obstruction to the free access and passage to and along the machine.

Messrs. William Russell & Son, Lawrence, Mass., are the owners of an invention which is an improvement on the ordinary sliding head. Fig. 65 is a perspective view and Fig. 66 a section through the middle of it.

A represents a section of round rubber packing, held loosely between two metallic heads B B and C C, the said packing being fitted so as to slide easily in the box when not compressed between the heads B B and C C. D is a brass journal or hub, with a male thread fitting another thread tapped into the half of the head marked C C. The cylinder E has a brass pipe F soldered to it, and can thus be made as long as may be desired. It ends with the head G inside, and extends to the outside of the suction-box with the pipe F, which carries there a hand-wheel, by which it can be turned.

Fig. 65 shows the form of the heads of D and G. By turning the hand-wheel on F, and with it the cylinder E and head G, the hub D can be moved to the right or left, the plate C moved in or out, and the rubber packing A pressed tight or set free.

A few turns of the screw loosen the packing and permit the sliding head to be pushed to any desired place, while a few turns the other way tighten the packing again. It can be seen from Fig. 65 that by giving half a turn to the head G it can be pushed out of D to the inside of the box. The rod or pipe F, instead of being an obstruction outside, can thus be always kept inside of the box, entirely out of the way. The collar H prevents the plate C from being screwed out altogether.

The position of these heads can be changed quickly; they close tightly, and are of simple construction.

To prevent the water from being forced out of the paper with more power near the point where the syphon-pipe enters the box than elsewhere, the suction-boxes have a false bottom with an opening in the centre. The suction-pipe may be fastened to any point of the lower chamber, as it cannot act directly on the wire.

The stands N^4 carry planks N^5, and on them, mounted on three iron frames, the suction-boxes. When a new wire is to be put on, these three iron frames are removed, the suction-pipes detached, the boxes lowered to the planks N^5, and pushed out to the front side of the machine.

The wire is subjected to friction on these suction-boxes, not only in the direction in which it runs, but also sideways from the shaking motion. This latter friction, though very slight and rather harmless, can be entirely avoided by hanging the boxes to the frame or bars E by means of bolts, so that they will be shaken with the wire.

Fig. 65.

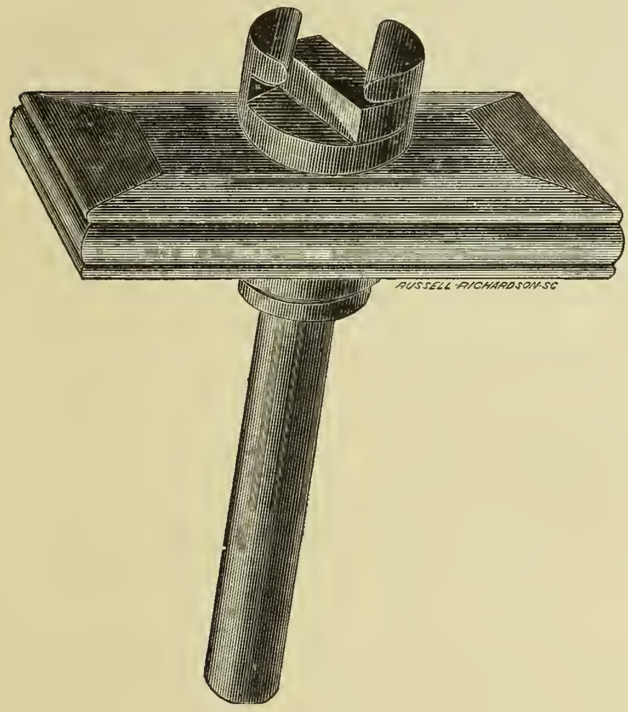
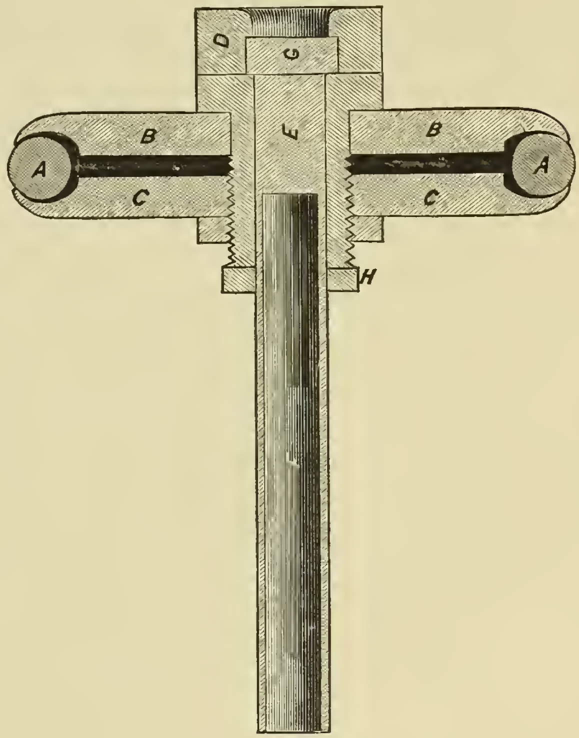


Fig. 66.



It has already been explained that the air must be thoroughly excluded from the suction-boxes. This is only possible if there is no hollow space left between them and the wire, if the latter fits closely all around. Great care must therefore be taken to have the boxes perfectly level and in line with the adjoining rolls.

When a suction-box refuses to work, it will mostly be found, that air has gained admittance somewhere; sometimes one side, or only a corner, does not touch the wire. We have seen much trouble from such simple causes, when, by raising the low corner or side by means of a key, perfect suction would be obtained.

By means of the set-screws N^6 in the stands N^4, the slightest changes in the position of the planks N^5 and of the boxes can be effected.

113. Dandy-Roll.—Two suction-boxes, at a short distance from each other, are supplied to most machines. Between them, if used at all, on top of the wire and supported by bearings O^3, fastened on the bars E, is a wire-roll O, open at both ends.

It is constructed of a hollow brass shaft with numerous brass spiders, which carry wooden or sheet-copper strips of the length of the roll. Strong wire is wound around the frame, thus formed, in numerous circles, and the wire-cloth is sewed to it. This is the dandy-roll O, justly named so, because it gives to the paper any desired fashionable appearance. It closes up the web a little tighter, and covers, like good cloth on a worthless body, some of its defects. If no particular mark or wove paper is wanted, the dandy may be covered with the same wire-cloth as that on which it runs. But if any water-mark or impression, such as laid, ripped, or squared paper, a name or figures are desired, wires representing every line of the design must be sewed on the cloth covering the dandy. If the design is to fill just one sheet, the circumference of the roll must be exactly as long as a sheet.

The projecting wires press into the already formed, but yet soft, paper and displace some pulp. The paper is therefore thinner in those places, and shows the lines through their greater transparency. With a skilfully covered dandy, water-marks of almost any pattern can be produced.

The friction received from the contact with the wire-cloth turns the roll, but if the latter is too heavy, parts of the wet sheet will adhere to it so closely that they are torn out. The dandy is therefore made as light as possible, and no weights or screws are used on it; for the same reason it is impracticable to make it of very large diameter. The bearings O^3 can however be set higher or lower by means of set-screws, thus regulating, to some extent, the pressure of the roll on the paper.

The stands O′ carry a wooden strip O^2, to which a piece of felting is tacked. This felting touches the dandy all along; it serves as a doctor, and retains particles of pulp which may be carried up from the web.

114. Save-All and Water-Pipes.—Between the suction-boxes and the breast-roll, close under the numerous little tube-rolls B, extends the save-all P, supported by stands on both sides. It is a flat wooden box, about 3 inches deep, receiving all the liquid which leaves the pulp above it, and emptying it into the fan-pump P′ previously described and represented by Figs. 51 and 52. The outlet from the save-all to the fan-pump is closed by a simple gate, and can be opened by pulling the handle P^2 on the front side of the machine.

To the save-all P is also attached on its lower side a wooden doctor-board P^3, which constantly scrapes the breast-roll A, and is therefore covered with felt on the touching edge. A water-pipe R′ pours in a little stream of water, by which it is kept clean.

A water-pipe R^2, with a goose-neck, is attached to the large supply-pipe R; a

rubber hose can be connected with it, and a stream of water provided at nearly any point of the machine.

As soon as the wire has left the couch-roll on its return trip, it is washed by a steady stream from a shower-pipe R^3. This is done for the purpose of removing any particles of pulp which may stick to the wire, and the shower will be as much more effective as the pressure of water, which can be brought to bear upon it, is stronger. The pipe R^3 should at all events be supplied from the highest available reservoir. If this washing is not thoroughly done, the pulp which adheres to the wire will be removed by the next roll D or D′ which it meets, and wind itself round it.

Wherever this is the case, mostly on the ends, the diameter of the roll is increased by the coat of pulp; the wire is thereby stretched, soon bulged out in all its length, and marks or breaks the paper. To correct these misfortunes the machine-tender, to whose inattention they must be ascribed, resorts to stretching the whole wire-cloth to the same length to which the bulged-out portions have been extended.

115. Stretch-Roll.—This he does principally with the stretch-roll D′, and he should take care to move the boxes G″ on both sides to exactly the same distance from the bars E, so that the roll will remain level.

Each time the threads of the wire-cloth are extended in this way, they are also weakened, and while even the length of a well-managed cloth increases through continued tension in the course of time, it speaks badly for the quality of either the machine, wire, or machine-tender, if it is violently lengthened by stretching. Many wires are not allowed to die a natural death from regular wear and tear, but are killed by repeated stretching, the result of the described causes, or of ignorance or neglect.

The much-used doctor will be found an efficient remedy against the collection of pulp on the ends or any other part of the rolls D and especially the stretch-roll D′.

It is represented in Fig. 2, Plate I, as attached to D′, and consists simply of a board S, supported by the iron hangers S′, which are fastened to the save-all P, and can be lowered or raised with the roll D′.

116. Stuff-Catchers.—A box, not shown in the drawing, extending under the coucher C and the shower-pipe R^3 receives all the pulp washed off from the wire by the latter. Whenever the machine stops or starts, some of the pulp, too thin to form a sheet, goes into this box, and it is here where the largest and most valuable portion of wasted stuff is gathered. It can, with difficulty only, be removed from there while the machine is running. It is preferable to let the contents empty themselves through a spout, starting from the bottom of the box, and leading to a stuff-catcher situated anywhere near or below the machine, so that the stuff can flow into it.

Sometimes all the pulp and liquid lost on the machine is gathered in a tub or cistern, and pumped into an upper story, whence it is drawn off to be used in place of the pure water, with which the pulp is usually emptied from the beaters.

Both receiving tubs, the one below the machine and the one above the beaters,

must be furnished with agitators to prevent the floating fibres from settling on the bottom.

If no such agitators are used, or if they are stopped for any considerable length of time, some of the mass, which sticks to the sides and lodges on the bottom, seems to undergo a rotting process or fermentation, and the whole liquid changes into a fluid of dark, impure color, damaging the paper for which it is used.

The waste water contains fibres, sizing and coloring matters, and deposits a dark slimy mass on the sides of vessels wherein it remains for some time, which even the agitators do not seem to prevent from settling.

Considering the power which is required to lift this waste water to the upper part of the mill, and the danger of having the paper spoiled by it, it may be found advisable to save only the fibres and to let the liquid run off.

Of the many stuff-catchers which have been constructed to accomplish this, a simple and effective one may be here described: It is built on the same principle as an ordinary rag-duster; only pulp is substituted for rags and water for dust. It consists of an octagonal cone open at both ends, with a shaft through its centre, suspended in a large wooden box or trough, on the short sides of which the shaft rests in bearings. Eight wooden frames are fitted to its surface, and held there by washers; they are very similar to those of an engine-washer, only larger, and covered with wire-cloth on the insides.

The waste water from the machine enters this cone at the smaller open end, while it is slowly revolved by a pulley on its shaft.

The water escapes through the wire and runs off, and the pulp gradually falls out at the wider end into a receiver with drainer-bottom, from whence it is removed and carried to the engines.

The larger end, where the pulp comes out, must be of circular form, and fit closely into another circle cut into the box in which it runs, so that the pulp outside and the liquid inside cannot have any communication. The longer the cone the better, but from 5 to 6 feet length will answer in most cases.

Besides the pulp from the couch-rolls any other waste from the machine can be led into this stuff-catcher, to save the fibres contained in it.

117. The Shaking Motion.—The two posts F and the frames H are respectively connected by iron cross-bars, so that both side-frames may be considered a unit as far as the shaking motion is concerned. The post F on the back or driving side of the machine has usually an elongation F′ upwards, and attached to its highest end is the connecting rod T, which communicates the shaking movement to the machine. It is placed high enough to allow a man to pass under it. A solid cast-iron, rather ornamental, column, called the shake-post, of which Fig. 3, Plate I, represents a section, contains an upright shaft T^1, driven at the lower end by bevel wheels T^2 T^2, which in their turn are moved by a pulley on the horizontal shaft T^3.

Bevel friction-wheels are sometimes used instead of the bevel cog-wheels T^2, but

as the friction on their surfaces may be reduced by grease, water, or condensed steam, their action is not so reliable as that of cog-wheels.

At its upper end the shaft T^1 carries a fly-wheel T^4, which can be turned by hand and serves to start the shake, and an eccentric T^5, to which the connecting-rod T is attached.

This arrangement is very expensive; and it has been suggested that a shake-arrangement, working on the floor instead of overhead, might be constructed much cheaper and would answer as well.

It is necessary that the speed as well as the length of the shake-movement may be quickly changed. A set of pulleys of different sizes, or cone-pulleys, give the different speeds, and the eccentricity of T^5, which can be easily changed by simply sliding the upright journal to one or the other side, determines the length of the shake.

It is this shaking movement, though it is very trifling (about $\frac{1}{4}$ inch), which makes the Fourdrinier paper superior to that made on a cylinder-machine. While without it, the fibres would only be laid parallel in the direction in which the wire runs, this cross motion makes them intertwine themselves in all directions, so that they will be felted as completely as hand-made paper.

It is evident that the structure and strength of the paper depends to some extent upon this movement, but only experience can teach what speed and length of shake should be used for a certain kind of stock and paper.

The shake must be regulated so that as much water as possible will have escaped through the wire before the paper reaches the suction-boxes; but, as the fibres will only felt themselves as long as they are suspended in water, it must also be prevented from leaving too soon. A tumbler full of water swung around very fast in a hoop reaches often a position in which it is upside down, without falling, and even without losing a drop, the circular motion being so intense that it overcomes the weight. This is exactly what fast shaking will do; the pulp is moved sideways so violently that the tendency of the water to fall through the meshes is checked. The shaking is strongest at the breast-roll and less as the wire advances, so that, even with a rapid movement, a free pulp will find time and room enough to discharge its water.

Long and slow stuff does not require much shaking, and though it has been only a little diluted in the mixing-box, it holds its water with great tenacity. Free and short stuff of rags, but more especially of straw or wood, loses its water faster than is desirable for the formation of a well-woven, tough sheet, unless it is strongly diluted and well shaken.

118. The Deckels.—The width of the paper on the wire is limited by a pair of deckels U on both sides. These deckels are always set a few inches farther apart than the width of the trimmed paper, to allow a margin for shrinkage on the dryers and for trimming.

The deckels are about $1\frac{1}{2}$ inch square endless straps of vulcanized rubber, which

have taken the place of those sewed together of cloth, as formerly used. They run over a number of flanged brass pulleys V and V′, two of which V′ V′ are fastened to a movable arm. By turning this arm up or down, and then fastening it with the set-screw V″, the deckels can be stretched to fit close on the rolls.

To prevent any sharp bends of the deckels, which might cause them to crack and wear out, the end-rolls must be large, the larger the better. The rolls nearest to the suction-boxes are fastened on to a separate shaft and stands, but all the other ones are supported by the brass frames W W, which are themselves carried on the shafts X X. These shafts X X are hollow brass tubes, the ends of which are filled with solid wrought-iron bodies. Iron screws, driven by a worm and worm-wheel Y, fit into these ends, and extend some distance into the brass tubes X, which are slatted out on their lower side to an equal distance. A brass nut, sitting on the screw inside of X, connects through this lower opening with a concentric collar or hub, which forms part of the frame W. The screw, being stationary, moves the nut, and with it the deckel-frame W in accordance with the turns of the worm-wheel Y, as directed by the crank Y′. The smaller ends of the tubes X which carry the brass-cased screws rest in ball and socket bearings X′, in which they can change their position. If these bearings were straight and the journals immovable, the shaking motion would exercise a constant strain on the tube X, with a tendency to spring or bend it. The two end-rolls or rather drums V are wide enough to allow the deckels to slide on them as far as the deckel-frames W can be shifted.

The friction of the wire is sufficient, without any driving-pulley, to communicate to the deckels its own speed, and, since it is indispensable that both should proceed together, this answers the purpose perfectly.

The frames W are stationary and not allowed to touch the deckels anywhere, as they might arrest their movement, and it is left entirely to the weight and tension of the deckels to make them lay flat and close on the wire.

The deckels must not be allowed to have any more play than necessary between the flanges of the carrying pulleys V, as they might move sideways to and fro, and give an uneven edge to the paper.

We have seen deckels slide out of their places on the first pulleys V and slip under the flange, where they pressed so hard on the wire as to crush and tear it in an incredibly short time. The accident was caused by the carelessness of the machine-tender, who did not adjust the deckel or the roll to its proper position; but it could not have happened if the flanges had been larger. There can be no harm in allowing them to project as far as half the thickness of the deckels from the bodies of the pulleys.

If the edges of the paper, on emerging from between the deckels, are not sharp everywhere, it is an evidence that the deckels do not lay close on to the wire at all points. It may be that there is an unevenness in the deckels themselves, or that one of them has opened in the seam—a fault which can easily be discovered; but in most cases it will be found that one or more of the carrying-rolls B are not perfectly in

line with the rest, and that the wire, where it is supported by the lower ones, leaves a hollow place between itself and the deckel, into which some of the pulp extends.

The part of the edge of the paper which has been deserted by these fibres has been weakened in proportion, and frequently to such an extent that it cannot withstand the tension to which the web is subjected on its march over the machine. The paper therefore cracks in those places; the rupture, once started, soon extends across the whole web, and the paper is broken.

It is of the greatest importance that all the rolls which carry the wire should be perfectly level and in line; no new cloth should be put in motion before it has been satisfactorily tested whether such be the case.

Sometimes we find that some of the tube-rolls B are not revolving, because they are placed too low to be touched by the wire, and this can easily be remedied by raising their bearings. Careless machine-tenders, who neglect to oil their journals well, and allow these rolls to stand while the wire is in motion, thus not only injure the wire by the increased friction, but the rolls themselves are flattened on the upper side, lose their balance, and refuse to work well afterwards unless they are again turned in a lathe.

The deckels must also be running perfectly square to these rolls, because otherwise the distance between them would be different all along, and the edges of the paper would become undefined and weak.

119. The Gates.—As soon as the stuff has left the apron it reaches the gates Z Z, consisting of brass sheets, which extend across the wire between the deckels, and are fastened to the frames W. Since their length must be variable to suit the different widths of paper, they are made of two pieces, sliding against each other, and fastened together by bolts. Their height above the wire can be regulated by a screw Z′ at each end; and to secure a sheet of uniform thickness, this must be done with great care. The paper cannot be of even thickness all across unless the lower edges of these gates are in every point equally distant from the wire.

As it is not desirable that a sheet should begin to form itself before the pulp has reached the gate, the leather or cloth extension of the apron must cover the wire to within about one inch from it. The wire in constantly pulling this leather, gradually stretches it forward until it sometimes reaches the gate, obstructing perhaps in one or more spots the passage under it. The paper becomes thin and weak in such places, and breaks. We have seen machine-tenders make broken paper for hours, because they did not pay sufficient attention to the gates and the apron.

The 3 to 6 inches space between the two gates Z are filled to some height with pulp, which receives here the strongest shaking motion, and being well diluted, intertwines the fibres more thoroughly than on any other part of the wire.

An inexperienced machine-tender may, in altering the gates or sluices, raise one end and lower the other, and perhaps reverse this on the second gate, thus making the production of a good sheet of paper impossible; but, not knowing the cause, he

will blame the wire for it, and probably not only stretch and ruin it, but make poor paper besides.

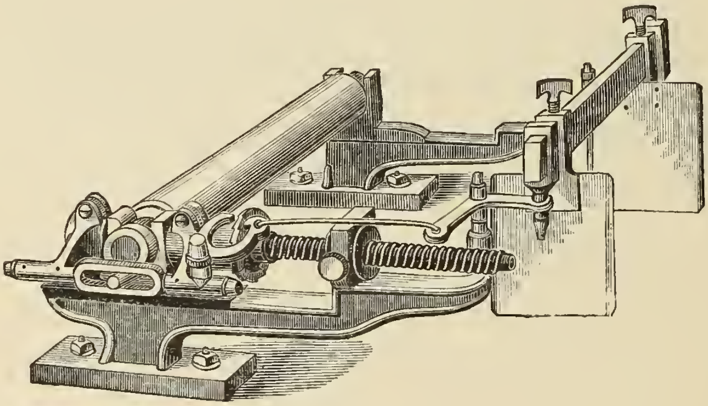
If the corners of the apron are fixed square and tidy, the gates perfectly level and opening just for the right thickness; if the deckels are square and running free and close on the wire, and the rolls are set in line; and if the pulp is of the right mixture, good edges will certainly be obtained.

120. Length of the Wire-Cloth.—The paper-makers of the United States seem to have settled on 33 feet as the most appropriate length of a wire-cloth; but if the speed is going on increasing at the rate it has done lately, the pulp will not remain sufficiently long on such a wire to form a sheet, and longer ones will become a necessity.

121. Wire-Guides.—It has been mentioned before that the wire is kept in its place by the guide-roll B′, which is regulated by the machine-tender. Many mechanisms have been invented to do this automatically, and some are used successfully.

Mr. Warner Miller, of Herkimer, New York, has introduced Thiery's wire-guide in this country, and it is now used on a large number of machines. A view of it is given in Fig. 67.

Fig. 67.



Any one of the rolls D (Plate I) which support the wire on its return trip may be used as a guide-roll in connection with this apparatus. The author has placed the guide under the save-all P, because space for it was more available there than elsewhere; but it had to be put on separate frames bolted to the sills in order to reach the wire. The two bearings of the wire-guide take the place of those G″ on the column G. The one on the driving side is stationary, but the one on the front side can be moved back and forward by a screw, with which it is connected. The wire passes first over the roll and then between two plates of sheet copper fastened vertically on a strip of wood, which is supported by movable levers.

If the wire shifts to either side it touches one of the copper plates, takes it along, and with it the wooden cross-piece. The angular lever on the front side is thus set in motion, and through it a double ratchet or hook connected with it by a wire rod.

A narrow brass cylinder or plate is stationed between the two points of the double ratchet or hook, teeth corresponding with the respective points are cut in on either side, and it forms thus a double ratchet-wheel. The double hook or ratchet receives a vacillating motion by means of a crank-pin, which moves in a sleeve and turns with the guide-roll. Whenever the wire shifts back or forward, one of the two points of the double hook comes in contact with the corresponding teeth of the ratchet-wheel, one side of which is cut to turn with and the other against the sun. The ratchet-wheel turns a nut on which it is fastened, and with it the screw and bearing of the guide-roll. If the wire shifts, for instance, to the front side, the screw moves the bearing forwards in the direction in which the wire runs.

This simple apparatus not only saves a great deal of labor and attention to the machine-tender, but prevents, especially on fast-running machines, the loss of many wires, which may be ruined in a very short time while the machine-tender is careless or employed somewhere else. Like all other improvements of this kind, the apparatus must be kept in good order; otherwise it is worse than useless, as it lulls the attendant's vigilance with a false security.

122. Patent Cleaning-Brush.—Where paper is made of very dirty or slimy pulp, the meshes of the wire become sometimes filled up so that they cannot be cleaned while running, and brushes are then resorted to, by the use of which it receives a severe rubbing while the machine is stopped. This proceeding, though it may answer the purpose, is very troublesome and injurious to the wire. The author has received a patent for a revolving cleaning-brush, pressed against the wire from below. This brush Q consists of a wooden cylinder studded with bristles, the iron shaft of which rests in bearings, which are supported by stands fastened to the sill of the wire-frame. It may be pressed against the wire either by weights or leverage, or simply held tight against it by fastening the bearings to the stands with set-screws. A small pulley on its shaft is turned by a belt and pulley from the coucher-shaft in a direction opposite to that of the wire. We have used it frequently, and it has never failed to accomplish its task. When the brush is not needed, it is let down out of reach of the wire, that it may not be unnecessarily used up.

If the wire is clogged up with fatty matters (printers' ink, paint, &c.), it is better to dissolve them first by shutting off all water and pouring coal-oil, or rather benzine, on the coucher C′, and then to start the wire and the brush.

123. Management of Wires.—We will here add some extracts from articles published by "Papyrus" (Adam Ramage) in Nos. 32 and 34 of the *Paper Trade Reporter* on the management and putting on of new wires:

"The wire is the most expensive as well as the most important part of the clothing of a Fourdrinier machine; the length of time it will run, and the quantity of paper it will make, greatly depend upon how it is managed in the putting on, and especially upon how it is run for the first few hours. A little carelessness or ignorance in its management at this time is often a source of trouble and expense as long as it lasts; consequently every precaution ought to be taken to insure it a fair start. When a new wire is to be put on, both machine-tenders and the helpers ought to be present; also the foreman

of the mill or some responsible person, who will guide and direct the whole operation, helping a little here and there, as he may be needed. While the machine-tender on tour is shutting down and getting off the old wire, and taking the felt-rolls out of the way, the other will get out the new wire to a safe and convenient place, take the jacket off the stretcher, punch the holes in each end, and run the lacing-twine through them; also get out all the planks and tools that may be needed, see that there is a supply of wiping-rags convenient, and a barrel of boiling water ready. About the time he has attended to these things, the machine will be ready for operations. All four hands are required to take off the top couch-roll, which should be lowered on to a plank, and moved along the frame, close up to the first press-rolls; the deckel-frame is next taken off and laid out of the way, the cutter hands being set to work to clean it thoroughly. And now, while one machine-tender is putting on the jacket, the other is getting out the tube-rolls, suction-boxes, and save-all, making everything clean and tidy as he goes, and laying everything away carefully and conveniently, so that there will be no delay when he comes to put them back to their places. Now is the time to have a place for everything, and to have everything in its place. To put a jacket on the couch-roll is now a very simple affair. Scalding the jacket with boiling water and punching it on with sticks is now numbered among the things that were; that it is so, all machine-tenders ought to feel thankful and say amen. The jacket is previously stretched on a frame while it is wet with boiling water, and allowed to dry thoroughly. It is now one and a half inches larger in diameter than the couch-roll. Any time after it is thoroughly dried it may be taken off the stretcher, a row of small holes punched in each end, and lacing-twine run through them, all ready to draw together after it is on the roll. After it is taken off the stretcher it must be kept perfectly dry; the least dampness causing it to shrink back to its original size.

"The old jacket is taken off and the roll rinsed clean with boiling water, the ends well cleaned, and rubbed with tallow. I use boiling water to rinse the roll with, because it heats the roll, causing it to dry quickly, so that the jacket may be got on and the ends fastened before it gets damp. A piece of pipe large enough to fit on the end of the couch-roll is now run through the jacket and slipped on to the end of the roll; by means of this pipe raise the roll, draw the box which the journal of the roll runs in loose aside, cover the frame with a rag or piece of felt, then draw on the jacket, push back the box to its place, and lower the roll. The jacket is now on the roll, but is quite loose; indeed, you may run your hand between it and the roll. The ends are now fastened by drawing up the lacing-twine and fastening it securely, being careful to divide the slack of the jacket uniformly round the edge of the roll. Now drench the jacket with boiling water (see remarks in Article 110.—THE AUTHOR), and it will shrink to its original size, or as near to it as the roll will permit. The whole is but a few minutes' work, and the roll is never taken out of its place. All hands will now turn to and clean up the frame and floor, and get out the breast-roll, which, when done, will make everything ready for the new wire. The pipe already used for the jacket is run through the loose end of the wire and slipped on to the end of the couch-roll as before, the couch-roll raised high enough to admit of the wire being carried right along over the roll; the roll is then lowered to its place and the wire unrolled to its full length, the breast-roll got in, and the save-all put back to its place.

"The hands may again divide, one machine-tender putting in the tube-rolls, the other the suction-boxes, and getting the water-pipes all straight again. When all the rolls are put into their proper places, the stretch-roll should be lowered sufficiently to take up all the slack of the wire, and set perfectly level. The wire started and allowed to make two or three revolutions, examine it carefully to see that it is a perfect wire. The deckel-frame and breast-board are now to be put on, then the top couch-roll, which ought to be put on with the greatest care. The men doing this ought to make a clean, steady lift, and be careful to lower all together, so that both ends of the roll will touch the wire at the same instant.

"It only remains now to put on the levers, and weights, and the guard-board, and set the stretch-roll, so as to make the wire firm and somewhat tight. The machine-tender on tour ought now to be left to himself to examine everything carefully, to see that nothing has been omitted or done improperly, then let him start the wire, and run it a few minutes to make sure that it is all right. Mean-

while let the others go to work and get the felt rolls back to their places, put away all the planks and tools, and everything that has been used, in their proper places, so that when next wanted they may know just where to find them.

"Now by following some such system as this a wire may be put on safely and expeditiously; there need be no hurrying, yet the machine may be shut down, the wire put on, and the machine started inside of four hours. But to accomplish this, the foreman, or other capable and responsible person, ought to be present. Besides guiding and directing everything, he can do much to clear the way for the machine-tenders, by making sure that the articles needed are on hand just at the right moment, and moved out of the way when used. A new apron may be wanted, which he can put on, or it may be the guard-board wants a new cover, or there is a rusty bolt or two that he can clean and oil. Indeed a capable and intelligent man will find his hands full of work at such a time, helping when he can, and getting out of the way when he is not needed. As far as it is possible and safe, machine-tenders ought to be allowed to do things in their own way, as in that case they feel themselves the more responsible for the behavior of the wire, and it is wise to have them both express themselves satisfied that it is all right when started; they are then the more interested in doing all they can to keep it so."

"The whole wire and all its belongings require the best care and attention that a machine-tender can give; he should never go near it when nervous or in a hurry; far better sit down and wait till his hurry is over, or go to the water-pail and hold his hands in cold water, and dash it over his face until he is cool enough to know what he is doing. The careless handling of a wrench or a brush, or a hasty, careless movement of the hand is liable to do it an irreparable injury.

"There is nothing more characteristic of a good, careful machine-tender than the care and attention which he bestows upon the wire. It makes no difference how much of a hurry either he or anybody else is in; he will not leave it on shutting down his machine until it is thoroughly washed off, nor will he start his machine until he is satisfied that his wire is all right; he will take particular pride in keeping it in one place, not moving the guide-roll more than two or three times on his tour. A machine-tender careless on this point is sure to be in trouble all the time. The wire, moving rapidly from one side to the other, makes the edge of his paper rough, causing it to break while he is taking the paper over the machine. He has to run back in a great hurry and move the guide-roll; ten to one he moves it too much or in the wrong direction; his wire is soon rubbing on the frame, or it is so twisted that he has to shut down, and take off the top couch-roll to straighten it."

IV. *The Presses.*

124. Press-Rolls and Housings.—The paper after it has left the wire is fully formed, and our efforts are next directed to free it from water.

The process of making paper by hand, where the sheets are exposed to a strong pressure, while lying between felts, is again imitated.

It is done by means of two or more presses, which are alike in principle.

Fig. 2, Plate II, gives a view of the two presses from the front side of the machine, and is a continuation of the part represented on Plate I.

Fig. 1, on the same plate, gives a view of the second press on which the manner of moving the doctor to and fro upon the surface of the roll, and the management of the clutch is shown.

The first or wet press consists of a pair of rolls A and A′, of not less than 12 to 15 inches diameter, the journals of which rest in upright cast-iron stands B on the

frames C of the machine. The lower roll A′ is connected by a coupling with a driving shaft on the back or driving side of the machine, and receives motion directly, while the upper one is turned by friction.

Both rolls A and A′ are of cast iron and mostly hollow, and though the upper one A may be very heavy, its weight alone is hardly sufficient to exercise the necessary pressure. Sometimes screws similar to A^2 are brought to bear directly on the journals of the upper roll. The pressure may thereby be considerably increased; but if any solid substance happens to get between the rolls, something must give way and break.

If levers and weights are used, the upper roll can be lifted up by the intruder, which passes through without breaking any part of the machinery. The presses in our drawings are provided with double leverage like the couch-rolls. The screw A^2, for which a thread is tapped into the cross-piece D, transmits the pressure to the roll A by means of the box A^4, to which it is fastened. The lower half of the journal is encircled by an iron band, which is bolted to the box A^4, and compels the press-roll to follow the movements of the screw A^2.

Instead of raising the roll A with a lever, and holding it in that position in the usual rather rude manner, by putting keys or blocks of wood between A and A′ whenever a felt is to be changed, the roll A is simply lifted up at both ends by a few turns of the hand-wheels A^3, which operate the screws.

While the machine is running, the cap or cross-piece D is not allowed to rest on or touch the housings B; it must be supported by the screw A^2 alone, and carries in its turn the rods D′ D′ at its ends. These rods are joined together below the stands B in a casting D^2, which is bolted to the lever D^3 near its resting-point D^4. The second lever rests and turns in D^5, is connected with the first one D^3 by a pin D^6, and carries the movable weight D^7, by which the pressure on the roll A can be increased or decreased.

An improved press-roll housing has been lately introduced, and is represented by Fig. 3, Plate II.

The screw A^2 and hand-wheel A^3 correspond with those in our Fig. 2, but instead of being keyed together, the hub of the wheel A^3 is tapped out, and the screw fits loosely in it. The eyes of the bolts D′, which connect with the yoke D^2, are only hooked into the short link Y, which is in the same manner suspended in the eyes Z Z. Whenever it is necessary to raise the press-rolls, the weights and levers are lifted up by hand, Y unhooked, and the bolt A^2 screwed up by the hand-wheel A^3. This hand-wheel is not permitted to rest on the housing while the rolls are at work, as the weights and levers would not be able to exercise any influence.

The principal improvement on the former construction consists, however, in the open or broken form of one side of the housing, through which the felts can be taken off and put on more conveniently than if it were closed on both sides.

Of whatever size or material the rolls may be, they must be made of greater diameter in the centre than at the ends, in order to press equally at all points. If

made perfectly straight or of uniform diameter, they will spring open in the middle and form a hollow place.

It is of the greatest importance that the two rolls should touch each other in a straight line through their entire length when the proper amount of pressure is put upon them, because the paper cannot lose as much water in a hollow place as in the other parts, therefore remains wet, is consequently weaker in that particular spot, and breaks on its subsequent journey towards the reel. A certain quantity of water is evaporated from every part of the paper on the dryers; the spot which has not been sufficiently pressed, and contains the most water, will therefore remain moist when the balance of the web is dry.

If passed to the calenders in this state the moist spot would stick to the rolls and probably be torn out; it is therefore natural for the machine-tender to admit more steam, and heat the paper until the moist spot disappears. The rest of the web, which does not require so high a temperature, is injured by being overheated, becomes brittle, and breaks frequently on the calenders.

When wet spots are seen in the paper the machine-tender should at once determine the cause and remove it. It may be that the guard-board does not fit close on the coucher, or that the coucher or one of the presses is weighted down too much or too little, that one of the felts is worn out or dirty, or that the dryer-felt is not in good order, &c.

The couch and press-rolls are, as before said, usually made a trifle full—sometimes $\frac{1}{64}$ to $\frac{1}{32}$ inch thicker in the middle than on the ends—and then require a pressure which is at all times strong enough to bend them into straight lines, and frequently stronger than would otherwise be necessary.

The weight, which must be brought to bear on the presses, depends not only on the quality and thickness of the paper, on the dilution of the pulp, and its treatment on the wire, but especially on the condition of the felts. While the felt is new and clean the water can pass through it easily, but a strong pressure is required after the pores have become partially filled up.

It is very difficult to construct press-rolls, especially for wide machines, so that they will not be too heavy, and yet sustain a strong pressure without bending. Their diameters, however, should always be large, and in proportion with the width of the machine.

Planche advocates the use of three presses instead of two. Each one of them would probably require less pressure; but it is doubtful if that advantage would not be offset by the increased difficulty of management, caused by an addition to our already complicated machines.

Imperfect or worn-out press-rolls are often made to fit one another by grinding them with flour of emery while they are running in their housings on the machine. They can be made to touch in all their length by this operation, but not true or straight, as the harder surface of one roll will rub into the opposite softer surface of the other one. It is also impossible to make them full in the middle by this method.

125. Brass and Rubber-Cased Press-Rolls.—The surface of an iron roll will rust when not in use; the rust is transferred to the felt as soon as the rolls start, and from it to the paper. The surface of the roll may be entirely smooth when new, but the rust will soon make it rough.

To avoid this and to secure a permanently bright and close-grained surface, the iron rolls are frequently covered with a brass casing about $\frac{5}{8}$ inch thick. Unless this brass cover is fitted very tight to the iron it may become loose in the course of time, and give much trouble. It is therefore bored out a little smaller than the diameter of the iron roll, made to expand by being well heated, and then forced, while thus expanded, over the roll by means of screw or hydraulic presses.

Press-rolls cased or covered with hard rubber of a brilliant, glassy-black appearance have lately been used and recommended on the plea that by their elasticity the natural elasticity of the fibrous web will be preserved, while it will be crushed and killed between unyielding metals. They are prepared by giving to the iron roll first a coating of vulcanized rubber, hardened so that it will stick well to the iron, and then a second outer cover of the same material not so highly cured, and therefore of a softer and more elastic character. If well made, these rubber coats have certainly good qualities and give satisfaction. They present a very smooth surface, and are largely used on lower press-rolls, where they are protected by a felt, and neither exposed to the action of a doctor nor liable to be injured or scratched by impurities in the paper.

126. Doctors.—The upper press-roll is always supplied with *a doctor*, which prevents parts of the paper or the whole sheet, when broken, from going all around and thickening on the roll, or, in other words, it keeps it permanently clean.

These doctors consist of a cast-iron body E′, somewhat longer than the roll, with journals on the ends, which rest in bearings E bolted to the stands B.

A thin steel, brass, or hard-rubber plate is secured on the body E′ all along, resting on the roll and scraping it. The levers E^2 fastened on the journals of E′ carry weights E^3 on their ends, and increase the pressure of the doctor-blades against the roll. Hard-rubber blades are stiff and hard enough for the purpose, while they do not cut the roll as much as metal.

It has been observed that the doctor-blades, if allowed to remain in the same position all the time, will cause the roll to wear unevenly into hills and hollows, and to obviate this a slow vibrating motion is given to them. They are driven to and fro upon the surface of the roll by means of attachments as represented on Plate II, or some similar mechanism.

The lever F in Fig. 1—swinging upon the pivot-bolt F′—is connected at its upper end with the doctor-frame, as shown, and its lower end has a point projecting into a spiral groove F^2 in the clutch of the lower roll. As the roll revolves, the vibrating motion is given by the clutch to the lever, which imparts it to the doctor.

This rocking motion of only $\frac{1}{2}$ to $\frac{3}{4}$ inch on the upper roll, together with the use of a hard-rubber blade, will keep the roll clean and the surface true.

127. Disposition of the Felts.—The paper is led through the first press in the same direction in which it moves on the wire, as indicated by arrows (Fig. 2). The felt G on which it is carried is marked with dotted lines and the paper with full lines.

The upper press-roll makes the side of the paper with which it is in direct contact more compact and smooth than the lower side, which rests on the felt; and in order to obtain a similar surface on both sides, it must be reversed in the second press; the side which was in contact with the felt in the first press must be brought in contact with the metal surface of the roll in the second press.

For this purpose the wet-felt G carries the paper underneath the second press and several feet beyond it to a point where it is taken off by hand, led over the two paper-rolls I I, and laid on the second felt G′. This second or press-felt G′, moving in a direction opposite to that of the pulp on the wire, as shown by the arrows, carries the paper backward through the second press. It will adhere to the upper press-roll and turn with it upwards to a point where it is taken off again, and led over another paper-roll, located above the press-rolls, to the drying cylinders.

The two presses proper are nearly identical in construction, and their component parts are therefore designated by the same letters in both.

128. Felt and Paper Carrying-Rolls.—Two distinct sets of rolls H and I carry the felts and paper respectively. Wood is the cheapest material of which they can be made; but, as they are exposed to constant changes of wet and dry, even those made of best-seasoned timber will lose their form and become warped and untrue. A roll which is not true is apt to do a great deal of damage by wrinkling the felt, or by causing the paper which it carries, to break. It is advisable to construct the rolls of materials which are less subject to the influence of heat and moisture, and will preserve them straight and circular.

The felt-rolls H are sometimes subjected to a very heavy strain by tightly-stretched felts, while the paper-rolls I have but little strain upon them.

The wider the machine is, or the longer the rolls are, the easier will they be bent; and their diameter should therefore increase with the width of the machine.

Wrought-iron tubes or pipes of from 4 to 6 inches diameter, with cast-iron heads well fastened in, will make very substantial felt-rolls; while copper or brass rolls of similar size are more suitable to carry the paper, as they run easily and can be made light, while they offer a smooth surface to the web, and will not rust.

When a felt is to be changed, the upper roll A is raised several inches by means of the hand-wheel A^3, the front-side journal of the lower roll A^1 is then lifted from its bearing by means of a lever or jack-screw, the old felt is drawn out over the roll A^1 between its front journal and bearing, and the new one is passed in through the same narrow opening. This can however not be done before all those carrying-rolls H, which are situated inside of the felt, are removed. The journals of all these rolls rest in cast-iron brackets with half-open bearings bolted to the frames, from which the rolls can be quickly removed without any previous unfastening of bolts or boxes.

129. Wet and Press-Felts.—All the water which is pressed out of the paper must pass through the felts, and, as the first press necessarily takes out a great deal more than the second press, the wet-felt must permit the passage of a larger quantity of water than the press-felt. The wet-felts are therefore of a light and open web, while the press-felts are thicker and heavier.

The standard length of wet-felts in the United States is 24 feet, and of press-felts 12 feet; the dealers are always supplied with felts of these lengths, and it is therefore advisable to build the machines so that they will fit.

Three qualities of felts are manufactured and used for corresponding grades of paper,—the superfine, fine, and common felts. It is a strange fact that only a few makers are able to produce a superior article of these felts; their values and prices vary therefore considerably according to their origin.

It is well known that every kind of woollen cloth, especially felts, shrink considerably when wet, the lower grades more so than the finer ones. They should therefore be always made from 6 to 8 inches wider than the press-rolls, and the frames should be far enough apart, and the felt-rolls H long enough, to give them plenty of room to spread.

130. Spread- and Stretch-Rolls.—To counteract the tendency to contract or shrink, one or more of the felt-rolls are covered with spirals or worms. These worms are made of two strips of heavy felting, about 1 to $1\frac{1}{2}$ inches wide, starting from a point in the middle of the roll, where they are fastened, and winding in spiral or screw lines around it, leaving at least two inches distance between the turns of the strips, until they reach the ends, where they are fastened again. To hold these strips on iron-rolls, they are sewed together in the middle, from where they start, and tied to the roll there and at the ends with strings.

These strips of felt thus form right and left-handed screws on the roll; the stretched felt, fitting closely on them, is spread out to both sides by the revolving roll, and kept from shrinking too much.

This system has entirely superseded the leather bands, which were formerly sewed to both edges of a felt, and held in their positions by a series of brass rolls, fastened to the frames.

Each felt is provided with one or two guide-rolls H′, by means of which it is kept in its place. If, for instance, a felt moves to the front side of the machine, the machine-tender advances the journal of the guide-roll on that side in the direction in which the felt runs over it, until it goes back. If the felt shifts to the back side, the guide-roll journal on the front side is screwed back against its line of travel, until it remains permanently in the middle.

The constant wear and tear weakens and elongates the felts, and it becomes often necessary to preserve their stiffness by stretching. The bearings H^2 of one of the rolls H, at a point where the felt takes a sharp turn over it, are carried on identical screws H^4 at each end. Both screws H^4 are moved by bevel wheels H^3, connected by a shaft across the machine, which is turned by the hand-wheel H^5 on the front side. The

length of the felts can thus be increased by twice the length of the screws H^4. The wet-felt being the longer, most exposed, and weaker web, should have plenty of stretch-room, or its screws H^4 should be as long as possible.

131. Felt-Washers.—The stuff, especially if short, well loaded with clay, or heavily-sized, will soon fill up the pores of the felts, so as to prevent the passage of water through them. To wash the wet-felt, a shower-pipe K is placed over it on the return trip, and immediately after having been soaked with water, it receives the friction or beating of two wooden wings L, fastened on a horizontal shaft below the felt, which is revolved with high speed by a small pulley on its back end. This washing operation, though it takes only a few minutes, necessitates stoppage of the machine, and various attempts have been made to have the felt washed all the time while it is running.

Whenever a felt begins to become filled up in some place, the paper is necessarily affected by it, and sometimes may be marked for some time before the machine is stopped and the felt washed. The water which cannot escape through that part of the felt remains in the paper, makes it weaker, and at last causes it to break. This is an additional reason why a system of permanent washing would be preferable.

We understand that an arrangement has been successful in France, by which the wet-felt on its return trip is first soaked by two shower-pipes, one above and one below, and directly afterwards freed from its surplus water between a pair of small press-rolls.

The second, or press-felt, does not require to be washed so frequently as the wet-felt, and nothing is therefore provided for this purpose. It is simply soaked with water, and receives a beating with sticks, in the hands of the machine-tender.

By this rough proceeding it is frequently ruined, and many paper-makers prefer therefore to change the press-felt whenever it becomes stiff or filled up, and to clean it outside of the machine in a felt-washer. In one large mill it is a rule to change the press-felts every morning.

Such separate felt-washers may be constructed of two wooden rolls, about 3 feet or more long, which rest in bearings on the sides of a box or trough. The ends of the lower roll should be provided with flanges or heads of a larger diameter, to prevent the felts from slipping out at the sides. The box is filled with water heated by steam, while the lower roll is revolved by a pulley and belt outside, and thus turns the felt which has been slipped over it.

The felt becomes soaked with water while it passes through the box, and is again deprived of its surplus by the pressure of the upper roll, which acts as a wringer.

Both wet and press-felts can be much better washed and rejuvenated, with boiling water and soap in this way, than on the machine.

132. Troughs below the Presses.—The water which is pressed out of the paper flows over the surface of the lower roll A′, and drops into the trough M, supported by the brackets or strips N N. This is in most cases a shallow and pretty heavy wooden box; but, as it must be removed whenever a felt is changed, it should be made of

some lighter material. A sheet of galvanized iron, bent in a circle of about 6 inches more diameter than the roll A′, and nailed on wooden segments which form the ends, will be found to be cheap, light, and convenient. This trough must be several inches wider than the roll, in order to catch all the water, and the joint by which a lead or rubber pipe is attached to the outlet M′ must be made with great care, to prevent any drops of water from leaking through. We have seen paper breaking for hours, until the cause was found to be drops of water, which escaped through the joint M′, and made wet spots on the felt below and consequently on the paper. A short metal pipe riveted to the outlet M′, near enough to the frame to be reached by the machine-tender, with a rubber pipe slipped over it, forms a safe connection.

133. Air-Roll.—Sometimes there is air between the paper and the felt G, which, as it cannot pass through the press, forms bubbles right before the rolls and bulges the paper out. To prevent this, a copper tube-roll O rests on the paper, and, pressing it by its weight, makes it impossible for the air to advance any farther.

134. Clutch.—Each press should be supplied with a clutch and lever, by which it can be either stopped or started at will. When, for example, one of the felts is to be washed, the press must run while the rest of the machine may stand still. The levers should be within easy reach of the machine-tender on the front side of the machine. The arrangement shown in Fig. 1, Plate II, is the same as that used for the wire and every other part of the machine represented on the plates.

The forked upper part of the lever R holds the movable part P of the clutch embraced; it pivots on the bearing S, which projects from the stand T, and its forked lower end is connected by a bolt with the flat iron bar R′. This bar R′ extends to the front side of the machine, where it connects with the lever V, which has its turning-point in the bolt V′ of the stand U. The hook or dog W, which is attached to the lever V, rests with its lower sharp end in corners of the same form, which make part of the stand U, preventing the lever V from falling back, and the movable part P of the clutch from drawing out of the stationary part. Whenever the press is to stand still, the dog W must be raised out of its position, before the lever V can be pulled back. If all the parts of this mechanism are strongly built, and the stands U and T well fastened on immovable foundations, it works well and is convenient.

135. Management of Felts.—It is of the greatest importance that the felt-rolls, as well as all other rolls, should be level, square, and parallel with each other. If only one of them is out of line, the felt may become wrinkled, and, passing through the press in that way, will be cut and ruined.

The rolls H must be placed in such positions that the felts make no unnecessary bends, and pass through the presses in as straight lines as possible, because every deviation from the straight course offers an additional opportunity for them to become twisted or wrinkled.

Felts, even if well taken care of, gradually wear out, and must be replaced by new ones; but careless or inexperienced machine-tenders ruin many, by allowing

them to become cut in the presses. If stabbed in that way, they can often be mended by sewing up the wound; but sometimes they are beyond cure.

A straight colored line is drawn square across every endless woollen felt by the maker. As long as this line is seen parallel with the rolls, the felt is running correctly; but as soon as one part of it runs ahead or lags behind, it is an evidence that one or more of the rolls are not set perfectly square and parallel, and the fault must be corrected by the guide-roll, until the colored line is straight again.

136. Taking the Paper through the Presses.—The paper is taken from the wire by hand, and laid on the wet felt, the first carrying-roll of which should be as near to the lower coucher as it can be placed, without obstructing the passage of paper and sometimes of thick pulp to the box underneath—not over 2 inches distant. It is, again by hand, taken from the wet felt to the press-felt, and from the upper roll of the second press to the dryers, as already described.

A narrow passage for the convenience of the machine-tender is usually left between the second press and the dryers, and a plank X, resting on the frames and bridging the felt and paper between the first press and the stretch-roll of the press-felt, provides another passage to the driving side.

V. *Dryers.*

137. Construction of Drying-Cylinders.—The first drying-cylinders were made of copper, but they have been almost altogether superseded by cast-iron ones, as the latter are less expensive, less liable to have their surfaces damaged, and will not change temperature as quickly as copper ones. In cases where iron dryers cannot be used, the brass or copper shell should be very heavy, in order to combine as fully as possible the advantages of both.

It is not only necessary that the surface of a dryer should be a perfect cylinder, but also that the body should be thoroughly balanced. It may be supposed that these cylinders, being held and driven by cog-wheels, will be forced to run steadily whether they are balanced or not; but it can easily be shown that this is not the case. We shall suppose, for example, that the cylinder has a heavy side or point, that it is in motion, and that the heavy side occupies just now the lowest possible position. On its way up from there, the cogs of its driving-wheel M [Fig. 1, Plate III] are pushed forward by the cogs of the next connecting-wheel M′, which thus sustain the extra weight, and move the cylinder as if it were well balanced; but on the way down, during the second half of the revolution, the heavy side will run ahead of the pushing cogs of the neighboring wheel M′ as far as the play between the driving and driven cogs permits. If the intermediate wheel M′ between the second and third cylinders is driven by the main gearing through a pinion, and if the dryer of our example is the last or fourth one, the motion is transmitted to it through five spur-wheels or four movements of cogs in one another. Each of the driven cogs must have some play between the driving ones, and if this is $\frac{1}{16}$ inch, the heavy side may

avail itself of all these spaces or of $\frac{4}{16} = \frac{1}{4}$ inch, until the accelerated motion thus produced is arrested by the cogs of the wheel or pinion on the main driving-shaft. Or, in other words, on the downward movement of the heavy side of the unbalanced dryer, the cogs of its driving-wheel, which have been resting on the driving-cogs of the next connecting-wheel, separate from them and advance downwards as far as they can, very rapidly; the paper on the cylinder partakes of this movement, and if suddenly pulled forward $\frac{1}{4}$ inch, it must break, unless it has enough elasticity to stretch itself to that extent, or sufficient strength to hold the faulty cylinder and prevent it from following the command of its heavy side.

The shells of dryers should be of uniform thickness, and therefore cast in loam, and it is for the same reason advisable to turn them inside as well as outside. The sand-holes, which are frequently seen on the surfaces of dryers cast in sand, not only make them rough, but, being often invisible, they open out only after they have been some time in operation, and must be plugged to prevent the escape of steam.

138. Admission and Escape of Steam.—The machine, parts of which are represented on the previous Plates I and II, has seven drying-cylinders, constructed like A, A^2, and A^3 of the following Plate III:

Fig. 1, Plate III, is a plan of four cylinders, two of which A^1 and A^2 are shown as sections.

Fig. 2, Plate III, is an elevation of the same cylinders from the front side, in which the two A^1 and A^2 are shown partly as sections.

Fig. 3, Plate III, is a side view of the automatic felt-guide, alongside of which it is drawn.

The steam enters the dryers through the main pipe B, the branch pipes C, and valves D. These valves D have a flange D′, which fits on the hollow journal E′, and a packing (usually an iron ring covered with cotton thread or lamp-wick) is placed between the two. By tightening the nuts of the bolts D^2, which connect the stationary bearing of the cylinder with the flanges D^3 of the valve D, the packing-ring is pressed until it prevents the escape of the steam.

If the water—the product of condensed steam—should be allowed to collect in the cylinders, it would reduce the temperature of the shell and the efficiency of the dryers. It must therefore be promptly removed; and this is done either by scoops or pipes, through the arrangements represented in the sections of A^2 and A^1 respectively.

The scoop is a cast-iron dipper F fastened to the back-side head with two bolts G, taking up the water with the opening or bucket F′, and emptying it through the channel F^2, which forms part of it, and through the connecting-pipe F^3. This pipe F^3 enters only a short distance into the journal, but, being packed tight all around with ordinary hemp or cotton packing, the water is effectually prevented from flowing back into the dryer.

The opening for discharge is constructed like that of admittance, but it has no valve, and the packing is pressed by the screw H′ threaded in the arched iron brace H.

The steam in the cylinder is perfectly free to depart through the scoop, to mix with the steam from the other dryers and escape through the waste-pipe. This waste-pipe I is often so arranged that the condensed water may flow through it without obstruction, and it then becomes a means of communication between all the cylinders, through which the pressure inside of all of them is kept nearly alike and independent of the openings of the valves D. The free communication of the pipe I with the outside air causes the steam to escape without having been fully utilized, and must result in a large waste of fuel. Live steam of high pressure will rush through faster and lose more than that which has previously been used and expanded in an engine. But it will be beneficial in either case if an obstruction to its free discharge through the outlet-pipe from the dryers is created by conducting the escape-pipe, which connects with I, so that it rises up again several inches above I in some point, and thus causes the water to accumulate in I and its upright branches to the same height. The cylinders will be separated from each other and from the air by this water, and the steam will be better utilized and condensed before departing.

The cylinder A′ is provided with an upright immovable escape-pipe K, extending to within about 1 inch of the shell, which, not being connected or turning with the cylinder, does not disturb the balance. It communicates through an elbow and a horizontal pipe K^1 with the stuffing-box K^2; and the threads of all these connections must be cut so that they would only be screwed tighter if the cylinder A′ should happen to carry the pipe K around with it.

If these escape-pipes are used in the place of scoops, the cylinders should be somewhat differently constructed from those shown on Plate III. The pipe K^1 should be as short as possible, and the stuffing-box K^2 should extend further in, while the head of the cylinder may be flat instead of arched. A hand-hole L in the head permits the introduction and adjustment of the pipe K.

The condensed water accumulates in the cylinder until it reaches the lower end of the pipe K, when it will be forced through by the steam-pressure into the waste-pipe I; it is thus constantly kept up to the inlet of the pipe K, but not higher, forming a gate, which prevents free communication between the different dryers and the waste-pipe I.

The hot water escaping from the dryers should never be wasted, but gathered, where it can be used for feeding the boilers or some other purpose.

139. Process of Drying.—The process of making paper by hand is closely imitated by the machine up to the dryers. Hand-made paper is, however, not dried artificially, but simply exposed to the air, and contracts to $\frac{9}{10}$ or even $\frac{4}{5}$ of its size during that operation. The fibres join each other closely in all directions, and produce a firm and tough sheet.

On the machine the paper can only shrink very little in the direction in which it runs, because it is constantly drawn out and stretched. Sometimes the original sheet, formed on the wire, is even lengthened out through the action of the presses. Nothing prevents the paper from shrinking in width or at right angles to the line in which it

travels; but it is usually dried so fast that it has no time to contract, and the sheet on leaving the dryers is found to be very little narrower than it is at the press-rolls.

By subjecting the paper slowly to gradually-increased temperatures, the natural way of drying by air will be imitated as much as possible, and the qualities of hand-made paper, its tough and yet pliable body, will be in a measure given to the product.

If the paper is dried fast and strongly heated, it will acquire qualities the reverse of those we aim at; it will be brittle, of porous appearance, and sometimes even badly sized, although the engineer may have sized the pulp in precisely the same manner which, until then, gave always good results. When the paper is too violently heated it becomes cockled and unfit for use, and must be worked over again.

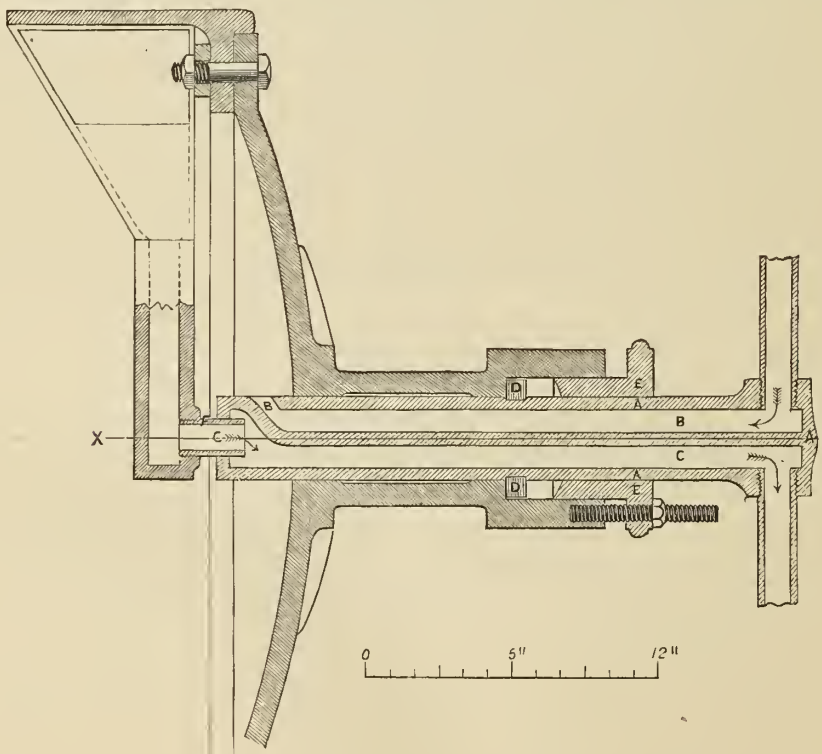
The larger the heating surface over which the paper passes, the better.

The greatest economy of fuel will be reached when the number of dryers is so large that all the steam used can be permitted to condense in them.

The first cylinder should have the lowest, and the last one the highest, temperature, and the steam-pipe, coming from the generator, should therefore connect with the pipe B at the end, where the paper leaves the dryers.

140. Improved Arrangements of the Steam-Pipes.—The dryers of a Belgian

FIG. 68.



machine at the last Paris Exposition were connected by pipes in such a way that the

steam would only enter into one or two cylinders, and on leaving them circulate through the preceding ones. This system would certainly heat a row of cylinders very gradually; but the large quantity of condensed water, which must be carried along from one to the other, would probably make it impracticable.

Some dryers have lately been built with both the inlets for steam and outlets for water passing through the journals of either the front or the driving-side only. This saves the packing-boxes and their connections on one side, and has been found to give satisfaction. The construction of this improvement, in connection with a scoop, is shown by a section in Fig. 68. The steam enters through the channel B from above, and the condensed water leaves through the channel C below, as indicated by the arrows. The turned cast-iron cylinder A is divided by a partition so as to form these channels; a wrought-iron ring D, shrunk on it, prevents it from entering too far into the cylinder, and forms the bottom of a stuffing-box, of which E is the movable part.

The short pipe F connects the scoop with the channel C, and must be well fitted to it, to prevent the escape of steam through the joint, as the scoop revolves while A is stationary. If a stationary escape-pipe, like K [cylinder A′, Plate III], were used instead of a scoop, this dangerous joint would be avoided.

141. Steam-Pressure Regulator.—The heat of the dryers is principally regulated by means of a valve on the main steam-pipe near the last cylinder. This valve should be more closed or opened whenever the pressure of the steam increases or decreases, which is very frequently the case if the steam comes directly from the boilers, where the irregular demands from other parts of the mill produce constant changes. If the temperature of the steam in the cylinders rises, the paper will be too dry, becomes overheated, and will break on the calenders; if it falls, the paper is not well dried, and wrinkles or breaks. Several forms of mechanism have been constructed, by which the steam-valve is to be opened or closed automatically whenever the pressure changes. The patented steam-regulator shown by Fig. 69, and owned by Messrs. William Russell & Son, Lawrence, Massachusetts, has found much favor, and has been adapted to many machines.

A brass-roll A, the bearings of which rest in stands on top of the frames, is inserted between the last cylinder and the preceding one, and the paper is conducted over it on its passage from one to the other. The boxes or bearings of this roll rest on brass spiral springs, and the one on the front side is connected through the brass rods C with the balanced steam-valve B, which admits the steam to the dryers.

A screw is cut on the vertical rod of the valve B, and fastened to the horizontal end of rod C by means of two nuts, one above and one below.

If the paper, which passes over the roll A, remains damp for want of sufficient heat or steam, it occupies greater length, and has more elasticity than if it were dry, and the roll A is pressed upwards by the spiral springs, raises the valve, and admits more steam. If the paper is heated or dried too much it contracts, draws the roll A down, and shuts off steam by closing the valve.

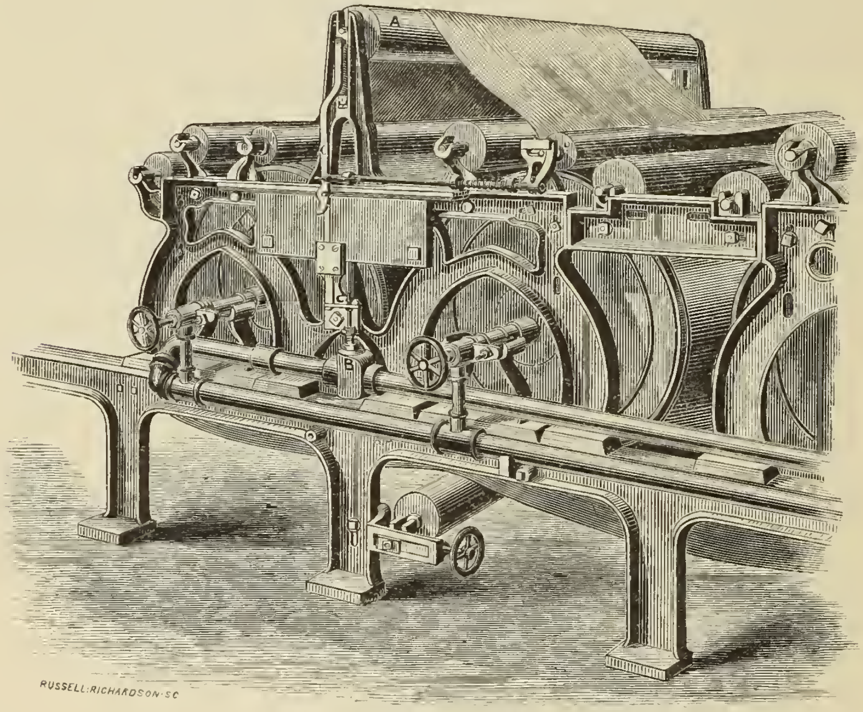
As long as the paper is dried as it should be, the roll A occupies a position at a

certain permanent height above the frame; but if the quality or the weight of the paper is changed, it will compress the spiral springs more or less than before, and the regular position of the roll A will be above or below the one which it had previously occupied.

It therefore becomes necessary to shorten or lengthen the rod C, or the distance between the roll A and the valve B, according to the quality and weight of the paper. This is, as explained before, done with the nuts which fasten the valve-rod to C.

The rod C is made of two parts: an upper one, which is held and guided between plates fastened together with four screws, as shown in Fig. 69, and a lower one, which is suspended by means of a projecting pin in a cavity of the upper part.

Fig. 69.



A horizontal rod connects the upper part of C right above the pin with the front journal of a paper-roll D on the dryer next to the last one. The usual bearing is replaced by one which permits the journal to slide back and forward. While the paper runs over D, the journal is in the position farthest away from C, but as soon as the paper breaks and leaves D, a spiral spring, fastened to a fixed point and wound round the horizontal connecting rod, pulls the roll D and the rod itself back to the end nearest to C. The upper part of C, being pushed in the same direction, leaves the pin by which it holds the lower part suspended; the latter drops down through its weight, and closes the valve B completely.

The object of this last described part of the regulator is to cut off the steam as

soon as the paper breaks; but by doing so it allows the dryers to cool off to such an extent that the paper cannot be dried if put over them a short time afterwards, until they have been heated again, and a good deal of paper may thus be left damp and will be spoiled.

If the paper breaks the machine-tenders prefer rather to waste some steam than to allow the dryers to cool off, and they only shut off steam entirely when the machine, or at least the production of paper, stops. On some machines which are supplied with the regulator, the roll D and its attachments are therefore dispensed with.

This regulator is highly valued because of the greater uniformity of the paper and the decrease of breakage or waste experienced through it.

142. Gearing, Size, and Disposition.—Every dryer carries on its journal on the driving side a spur-wheel M, connected with the adjoining ones by intermediate spur-wheels M′, and one of the latter, usually the middle one, driven from the line shafting by means of a countershaft and pinion, sets all the others in motion.

If the paper loses at all in length while on the dryers, the shrinkage is so little that no notice need be taken of it; the cylinders are therefore made of exactly the same diameter, and run with the same speed.

The first paper-machines built in Germany were provided with only one drying cylinder of large diameter; but a comparison of that system with our present one explains easily why it has been abandoned:

> Three cylinders of three feet diameter, for example, offer to the paper a heating surface of $3 \times 3 \times 3.14 = 28\frac{26}{100}$ feet length, while their six heads have an exposed surface of $6 \times \frac{9}{4} \times 3.14 = 42\frac{36}{100}$ square feet. One cylinder of nine feet diameter will accommodate 9×3.14 or $28\frac{26}{100}$ feet length of paper like the three small ones, but its two heads occupy $2 \times \frac{81}{4} \times 3.14 = 127\frac{16}{100}$ square feet.
>
> All the heat, which escapes through the heads, is lost, and as the two heads of the large dryer offer three times as much surface as the six of the three small ones, the latter are, everything else being equal, more economical as far as heat or fuel is concerned.
>
> The temperature of a series of cylinders can be graduated, as explained before, while the paper is exposed to the same degree of heat so long as it remains on the large one.

The construction and management of small cylinders are easier than of large ones, and the paper-makers and engineers seem to have fixed about 30 to 40 inches diameter as the most desirable size for dryers.

They are sometimes disposed in two or even three tiers, in order to bring each side of the paper alternately in contact with the hot surface, the upper side of the paper on the lower row, and the lower side on the upper row. The saving of room may also be an object in this arrangement.

Since good calenders, especially those of chilled rolls, have been added to the paper-machine, the surfaces are so well glazed that a difference between both sides, on account of one-sided contact with the dryer can hardly be observed. For conve-

nience and easy management one row of cylinders close to the ground is much to be preferred.

If dryers are piled up on top of each other, the steam which rises from the lower ones is not only prevented from escaping freely by the upper ones, but it will also dampen both felt and paper on them. Each row of cylinders also requires a separate dryer-felt.

Though as much of the surface of the cylinders as possible should be covered by the paper, a small part must always be kept open, to facilitate the escape of steam and to allow them to be cleaned while running. On the lower row this open space is left on top, right under the eye of the machine-tender; while the upper cylinders have the exposed surface below, often difficult of access, and certainly of very little assistance for the free discharge of vapor.

In most modern machines all the dryers are placed in one row, and must impress everybody favorably by the simplicity of the arrangement as compared with the several tiers in which they were disposed in former times.

143. Quantity of Fuel required for Drying Paper.—It has been found by theoretic calculation, as well as from experience, that about $\frac{1}{2}$ pound of coal is required to produce steam enough wherewith to dry 1 pound of paper. The fuel, boilers, pipes, number and arrangement of dryers, &c., modify this quantity; and in some mills, where, on account of insufficient heating surface, high-pressure steam must be allowed to rush through the cylinders without condensing, 1 pound of coal or more is used to dry a pound of paper.

144. Dryer-Felts, Carrying-Rolls, and Guide-Rolls.—The best dryer-felts are made of wool, woven into a thick porous cloth; but they are so expensive in the United States that cotton-duck, similar to that used for sails, is generally used. This cotton-duck is manufactured in pieces of about 80 to 100 yards or more; from which the necessary length must be cut off, put on the machine, and the ends sewed together in a substantial manner. The seam should be smooth and its edges turned outward, so that it cannot make any impression on the paper.

A number of felt-rolls N, paper-rolls N′, a felt-stretcher O, and a guide-roll N^2, form part of the equipment of the dryers. They are constructed like the corresponding pieces of the presses, and everything that has been said about them under that head applies here also.

Self-acting guide-rolls have been successfully introduced for these felts. Their construction can be seen in Fig. 2 and Fig. 3, Plate III. The bearings P of the guide-roll N^2 rest with their lower cylindric ends or pins in the short levers P′, and can turn in them. These levers P′ are fastened with the set-screws P^2 to the upright columns P^3, which turn on pivots and carry at a right angle with P′ also the longer levers P^4. Shield-like plates P^5, facing the edges of the felt, are fastened to the ends of P^4, and if the felt moves to one side, it pushes the plate P^5 on that side in the same direction, and the bearing P of the guide-roll follows at a right angle.

Whenever the felt shifts to one side, the machine-tender advances the journal

of the ordinary guide-roll on the same side in the direction in which the felt runs over it; and this is exactly what our guide does automatically, if it is well made, carefully oiled, and if all its parts move easily and without friction.

The ordinary guide-roll is preferable to an automatic one, if the latter does not work easily or if it is not kept in good order, because it will then deceive the machine-tender with a false security, draw off his attention, and cause accidents.

If any one of the felt-rolls is not level or square, or if broken paper has wound itself round some part of a roll, increasing the diameter there, the felt will be stretched more in that place than in others, ultimately run in wrinkles, and mark or break the paper. When a part of the felt has been thus bulged out, it would require, in order to lay flat, more room than was originally assigned to it; the extended part is therefore flattened out by being doubled up into a wrinkle. The wrinkle is pressed closer on the hot dryers than other portions of the felt, it soon becomes so weak that the threads will not hold together any longer, and a hole is the consequence. It might have been avoided by closer attention on the part of the machine-tender; but the only remedy now is to cut out the extended or surplus piece, and sew the hole up again.

Dryer-felts, and especially those of canvas, are quickly made brittle or burned if allowed to remain on highly-heated dryers uncovered by paper. Whenever the flow of pulp is shut off, the steam should also be turned off immediately.

If any one of the heads of the dryers does not close tightly, or if drops of water leak through some bolt-hole, they will flow on the felt and wet it near the edges. The paper which is carried on these wet parts cannot become dry, remains weak, breaks frequently, and the felts themselves are also quickly ruined by being by turns wet and dry. Whenever such a leak is discovered, it must be stopped at once, either at the mill or at a machine-shop; but it cannot be fixed to remain permanently tight if all the joints are not turned or planed smooth and straight.

The felts used to be dried formerly on special small cylinders, which are now generally dispensed with. As the dryers are situated in one row, covered by one canvas felt, the steam escapes principally from the open space on the cylinder and above the canvas, and the moisture which the latter may contain has a good opportunity to evaporate on the long return-trip under the cylinders.

145. Width and Number of Dryers.—The deckels limit the width of the paper to that of the wire, less about 3 inches (their own thickness), and the heating surface, or width of the cylinders clear of the heads, must be at least as much. The portion of the shell which covers the heads of the cylinder is not in contact with steam—the heat is only conducted to it through the iron—and it should not be counted as heating surface.

It has already been said that it is desirable to have as large a drying surface as possible, and we will only add, that less than five cylinders of 3 feet diameter will hardly be sufficient for any paper-machine with the speeds used at present; but for fast-running machines and heavy papers, many more are needed, and their number

may be increased to ten or twelve with good results. At least seven or eight 3 feet dryers should be used for a machine making 100 to 125 feet of light printing paper per minute.

VI. *Calenders.*

146. Object and General Construction.—The calenders consist mostly of iron rolls, placed in a stack or nest. The lower roll is coupled to a shaft driven by belt and pulleys, and all the others are moved by friction. The surfaces of all the rolls, of whatever diameter they may be, have therefore the same speed.

The machine-tender takes the paper from the last dryer by hand, puts it between the uppermost pair of rolls, and guides it all through the stack. The object of this operation is to compress the web, and especially its surface, so that the pores or hollow spaces between the fibres will be filled up, and the whole mass solidified.

Paper, like other materials polished in a similar manner, acquires thereby a smooth, glossy appearance.

To produce a uniform sheet, it is necessary that the rolls should fit perfectly on one another, and that their surfaces be true and smooth.

If the light shines through between the rolls while they are standing or running empty, it is an evidence that they are not true; if their surface is rough, they cannot be expected to give a smooth one to the paper; and in neither case are they fit for the duty allotted to them. Their polishing power is proportionate to their weight or pressure; they are therefore made heavy, and weights on a leverage, or screws, are brought to bear on the upper roll. Everything that has been said about the levers, weights, and screws used on the presses may be repeated here. If they exercise too heavy a pressure on the ends, the calender-rolls must spring up in the middle and become useless, like the press-rolls.

If all the rolls are cast solid, and the top one is made very large (not less than 12 to 15 inches diameter), the necessity of using extra pressure on the ends is entirely avoided. The bottom roll carries and moves the whole stack, and is entitled to the same or a larger diameter than the top one; but all the rolls between these two may be varied to suit the intentions and views of the manufacturer.

Whenever the paper passes between two rolls, it is subjected to the polishing pressure; the greater therefore the number of rolls, the more effective is the stack. On the other hand, very small rolls have little weight, and cannot exercise the same pressure as large ones; but their smaller and sharper circles act more acutely upon the paper.

147. Passage of the Paper over the Rolls.—The machine-tenders lead the paper by hand round the rolls far enough to make sure that it will pass in the right place, and it requires a calm, collected mind, a quick eye, and nimble fingers to withdraw the hands always at the right time.

Most machine-tenders have had their fingers drawn in or nipped, and the hands of many will carry the mark made by the calenders to the grave.

While some will never learn to put the paper through properly, most men can train themselves to it by practice and experience. The smaller the rolls are and the faster they run the more difficult it is to lead the paper through, and as long as this must be done by human fingers, they put an effective limit to the otherwise desirable reduction of the diameter of these rolls. We have seen fine stacks of calenders standing idle, because nobody could pass the paper through them at the speed the machine was running. Three, five, or seven rolls of about 8 to 9, 6 to 7, or 5 inches diameter respectively, between the top and bottom ones, will answer in most cases.

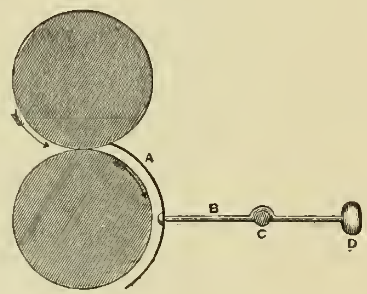
The substitution of some mechanical contrivance for the machine-tender's fingers at the calenders would be a desirable improvement.

Mr. Harper's mill at Westville, near New Haven, Conn., is the only one where we have seen an attempt of this kind made.

The fingers used there and represented by Fig. 70 are in principle like those used on sheet super-calenders.

The circular piece of flat spring steel is riveted to the horizontal lever B, which rests on the rod C. Two of these short rods C are fastened to the calender stands for every roll; they reach far enough in to catch the edges of the narrowest paper made with the finger A. The rod B is flat, balances on C, and can be placed on any part of it; its end D being just heavy enough to hold the point of A against the roll, without exercising a pressure which might damage it.

Fig. 70.



We have been assured that a set of steel fingers of this kind leaves nothing to do for the machine-tender but to lead the paper in on top and take it away below; but if they should not give perfect satisfaction, we would suggest that the addition of guide ribbons, such as are used for sheet super-calenders, might answer the purpose.

The paper is always led in on top and out at the bottom, because the pressure should increase as it advances, and in this way one more roll is added to the weight of every preceding pair.

148. Quantity and Quality.—The number of stacks which may be used in one machine can hardly be limited, but seldom exceeds three, and one or two only are usually seen.

Their quality is more important than the quantity, as they will have no effect whatever unless they are constructed in a thorough and substantial manner.

The frames and bearings, carrying the journals of the rolls, must be substantial and carefully made to enable the rolls to rest upon each other perfectly straight, their centres forming a vertical or plumb line. If the rolls are not put up in this way, if they cross each other, they will twist and wrinkle the paper between them.

The continued friction of the paper, especially of lower or medium grades, wears out common iron rolls in an incredibly short time. It gradually wears an opening

as wide and as thick as the sheets, while the ends through which the paper never passes remain intact and keep the rolls at the original distance. When the calenders have reached that condition they are of no use, and must be taken out and turned or ground off. If made of pretty hard iron, and kept in good order, they may give satisfaction, but if they are soft, and must be frequently turned off at a heavy expense, it will be found more advantageous to dispense with them altogether.

149. Chilled Rolls.—Chilled rolls, with a hard steel-like surface, are now justly taking the place of common iron ones.

They make a better surface because they are harder, and last for years without being redressed or ground. They are cast in thick iron moulds called chills. The contact of the molten iron with the cold chill produces a change of texture in the surface of the roll, turning the iron into a close-grained, fine metal, resembling steel. This transformation is most perfect at the surface, decreases towards the centre, and leaves the main body unaffected. A change of texture may be observed in such rolls as far in as one inch from the circumference.

The following quotation is taken from an article on this subject in No. 13 of the *Paper Trade Journal.*

"The iron used is the first consideration. It must be 'charcoal' iron, that is, iron smelted with charcoal as fuel. It must be a 'chilling' iron, that is, an iron which, when melted and poured into an iron mould, will have its surface, for a depth of from a quarter of an inch to two inches, hardened or 'chilled,' the interior remaining soft or in the usual condition of sand castings. It is a matter of the utmost delicacy to have the quality of the iron proportioned to the casting it is desired to make. For example, the iron used for casting a 12-inch roll, if used for a 6-inch roll, would chill to the centre, and make a casting so brittle that it would not support its own weight. What we want in rolls for paper calenders is such an iron as will make a chill from a half inch to one inch in thickness.

"The moulds in which the metal is cast are of iron, varying in size according to the size of the roll to be made, and are technically termed 'chills.'

"These chills are pipes or tubes, from two inches to six inches in thickness, to absorb quickly the heat from the melted iron, by which sudden cooling the 'chilling' is effected. In casting, the chill stands perpendicular, and the necks or ends of roll are moulded in sand in the usual way. The iron is poured through a channel exterior to the mould, so that it enters at the lower end, and rises up through the chill, till it flows out at the top of the mould. When cool, the casting is removed from the chill, and is ready for the lathe.

"A lathe for turning chilled iron has but slight resemblance to the lathes ordinarily seen in shops. Strong and ponderous, it moves but at a snail's pace; in fact, about one-twentieth of the speed at which lathes ordinarily move in turning iron. It is necessarily a work of great labor and much time to turn a chilled roll, owing to its great hardness; but let us here remark to those whose expectations may be too high, that a chilled roll, though hard, is yet softer than the steel which cuts it. The steel itself is cut by the sand in a grindstone, and therefore no roll which can be made, be it even of hardened steel, can crush the sand in paper with impunity. We mention this, as those manufacturers who expect to use chilled rolls both as calenders and crushers may be disappointed."

The surface of good chilled rolls is very little softer than the hardest steel, and the difference in hardness is not sufficient to admit of their being turned with steel tools in the ordinary manner.

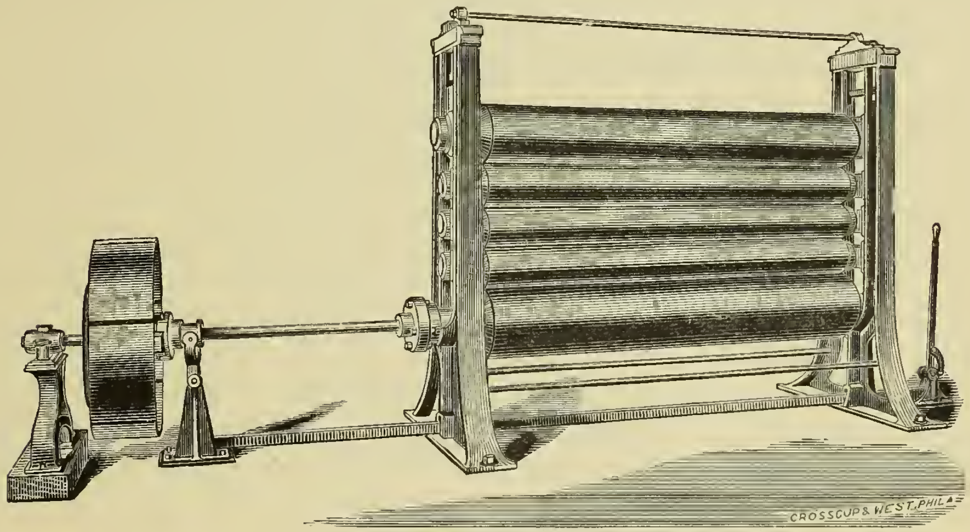
They are ground in a machine which is built like a lathe, with the difference

that the cross-head or wagon is not one-sided, but extends all across the bed, and carries two corundum wheels, which grind the roll on both sides at once. Corundum is a mineral of the sapphire family, in hardness next to diamond. It is crushed to powder and mixed with gum shellac, thus forming a paste, from which the corundum wheels are moulded under a heavy pressure. These wheels are made about 9 inches diameter and 2 inches wide, and used until they are worn down to a few inches in diameter.

The wheels are pressed against the roll by means of screws. They are driven by separate belts from a shaft above the lathe, and revolve with nearly three thousand revolutions per minute, moving with the cross-head and grinding all the time, while a stream of water flows constantly on to the roll, to keep it cool and clean. The work of the attendant consists principally in tightening the grip of the grinding-wheels.

Two grinders are used instead of one, because they do more work, and prevent the roll from being sprung out by the one-sided pressure of one grinder.

Fig. 71.



The grinding machine must be constructed with the greatest accuracy, so that the saddle carrying both wheels will be moved in perfectly straight lines.

The stack of calenders represented in Fig. 71 has chilled rolls, an expansion pulley and a clutch arrangement, by which it can be quickly stopped and started from the front side.

150. Steaming the Paper.—The paper, coming fresh from the dryers, is rather hard, and cannot take the impression of the calenders as easily as if its surface were somewhat humid. The dry paper is therefore frequently moistened with steam before it passes through the calenders. An iron steam-pipe about $\frac{1}{2}$ inch wide with numerous holes as large as pin-heads, which might be called a steam shower-pipe, is fastened to the frames of the calenders, a few inches below the sheet, where it first enters.

As soon as the valve is opened, little jets of steam start all along from the holes in the pipe, striking and moistening the paper. If it should be found desirable, two of these pipes may be used, one on each side of the calenders, to moisten both sides of the paper.

The steam from these shower-pipes strikes the rolls and makes them wet, whenever the paper breaks and leaves the calenders uncovered.

Mr. Frank Fletcher, of Newark, Del., overcomes this difficulty by a very simple arrangement, which shuts the steam off automatically when the paper breaks, and admits it when it is running right. A round block of light wood, about 5 inches long and 1½ inches diameter, rests freely on the middle of the web of paper between the dryers and calenders. It is attached to a light iron rod, which ascends a short distance in a perpendicular line; then proceeds in a horizontal direction parallel with the rolls to the front side of the machine, and down again to the end of a lever, which opens and closes the stop-cock on the steam-pipe supplying the shower. While the paper is moving, the wooden block simply rests on it, but it falls a few inches until the rod is caught at its upper end in a hook or wire sleeve, whenever the paper breaks. It is permitted to fall just enough to close the steam-cock, and reopens it as soon as the paper runs through and carries the block again.

Mr. Fletcher uses a steam shower only against the side which has been in contact with the surface of the dryers, as it is the hardest, while the other one is comparatively soft and moist. The steam meets the paper on the forward side of the calenders, where it descends over the top-roll.

Every steam shower-pipe must be provided with a bent sheet of tin or a trough, by which all the water which may escape with the steam is caught and carried off.

This steaming process not only improves the surface, but also increases the weight of the paper and draws off its electricity.

Calenders, if very large, require a considerable amount of power, and the belts, if not long and wide, frequently slip, and cause the paper to break.

To prevent trouble from this source the calender-shaft is sometimes provided with a spur-wheel and driven by a pinion.

VII. *Reels.*

151. Different Styles of Reels.—Before the invention of paper-cutters for endless webs, the paper was usually taken through the slitters after having left the calenders, and then wound up on reels. After a roll of considerable thickness had thus been formed, it was cut through in a straight line, parallel to the reel shaft, placed on a table, and cut by hand with a long knife fastened to it for that purpose. These reels are yet used in some mills, and constructed so that the wooden cappings can be moved in or out to increase or decrease the diameter. They must be adjusted to make the circumference a little longer than the desired sheet of paper, leaving a margin for trimming.

If the sheets are to be, for example, 36 inches long, the diameter of the reel must be about 12 inches; and if a roll of paper of 2 inches thickness is wound up on it, its outside diameter will be $12 + 4 = 16$ inches, and the length of the outside circumference 48 inches or one-third more than desired. The average waste produced by cutting the paper down to 36 inches will be over one-half of one-third, or one-sixth of the whole production of the machine.

This enormous waste would be sufficient to encourage the addition of paper-cutters to the machine, even without the saving of labor which they effect.

The American paper-makers seem to be well aware of this fact; for the old system of cutting cannot be seen in this country except in mills where tissue-paper is made.

The paper, before it is allowed to go to the cutter, is invariably wound up on reels. The cutter, being supplied from full or finished reels only, can be stopped or started while the machine is running, and is to a large extent independent of it. It is also desirable that the cutters should not run too fast, and this is attained by cutting the paper from two or three reels, that is, two or three thicknesses of paper at once.

To do this the machine must be supplied with at least three or four reels, two or three of which feed the cutter, while one receives the paper. The reels are fastened either on stationary or revolving frames. The stationary frames hold three reels perpendicularly, one above the other. Their construction is simple, but the number of reels cannot well be increased, as a fourth one would have to be placed so high as to be out of convenient reach.

If only three reels are provided—especially to fast-running machines—the cutter must work very well in order to empty them as quickly as they are required by the constantly arriving paper; and if they are stationary, they have the additional disadvantage, that the paper is drawn by every one of them in a different direction from the calenders.

The revolving frames, which admit of the use of from four to six reels, are easily manipulated, draw the paper always in the same direction, and deserve the preference.

152. Construction of Revolving Reels.—One of them forms part of the machine represented on our plates, and is shown in a side and front view by Figs. 72 and 73.

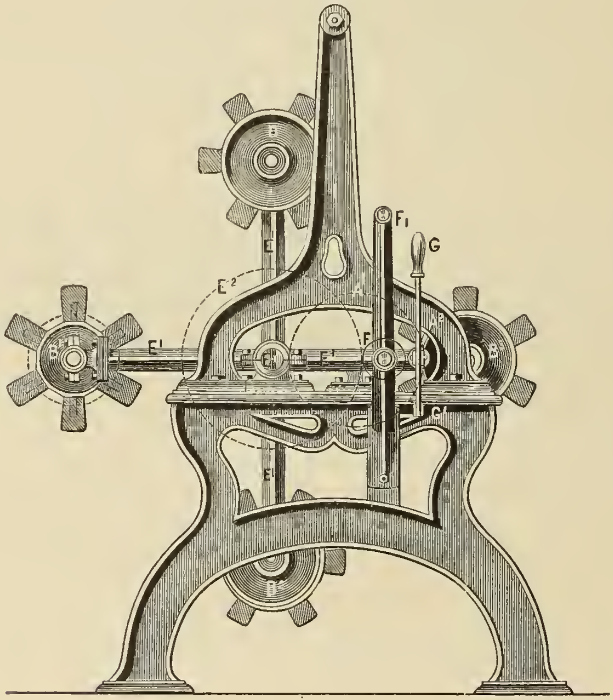
Each of the reels B B′ B^2 B^3 carries on its shaft a spur-wheel A^2. Our drawing shows B^3 in position to receive the paper and its spur-wheel A^2 in contact with the driving wheel A′, which receives motion through the pulley C and the short shaft A. As the paper is wound up the diameter of the reel, or rather of the paper-roll increases, and if the number of revolutions remains unchanged, the paper, being drawn with a constantly increasing speed, must inevitably break. The pulley C is therefore loose on the shaft A, and moves it by friction only. The collar D′ is also loose on the shaft; collar D is fastened on A with a set-screw, and pieces of leather of the same diameter as the collars are placed between them and the hub of the pulley C. The

shaft A is slatted out for the key D^2, which is held in position by means of two pins and by a notch in collar D′. A set-screw D^3, bearing on a light rod in the hollow centre of the shaft, presses the collar D′, the pulley C, and the leather rings against the fixed collar D, producing a friction between those parts which can easily be increased or reduced as may be desired.

The portion of the shaft A, between the set-screw and the pulley C, is shown as section, for the better explanation of this friction arrangement.

The pulley C thus moves the collar D and with it the reel, and as the tension of the paper becomes stronger with the increasing diameter of the roll of paper, it over-

Fig. 72.



comes the friction between the leather and the pulley, and the latter slips a little. It is the machine-tender's business to regulate the friction by means of the set-screw D^3, so that the paper neither breaks nor becomes slack.

The reel shafts are fastened on the arms E′, which are keyed to, and turn around with, the shaft E. A spur-wheel E^2, on the same shaft E, is turned by a pinion F and crank F′ on the front side of the machine. Whenever a reel is filled with paper, it is moved by this gearing and crank F′ until it has reached the position of B, and an empty reel has taken its place; the paper is then broken through and wound up on the latter.

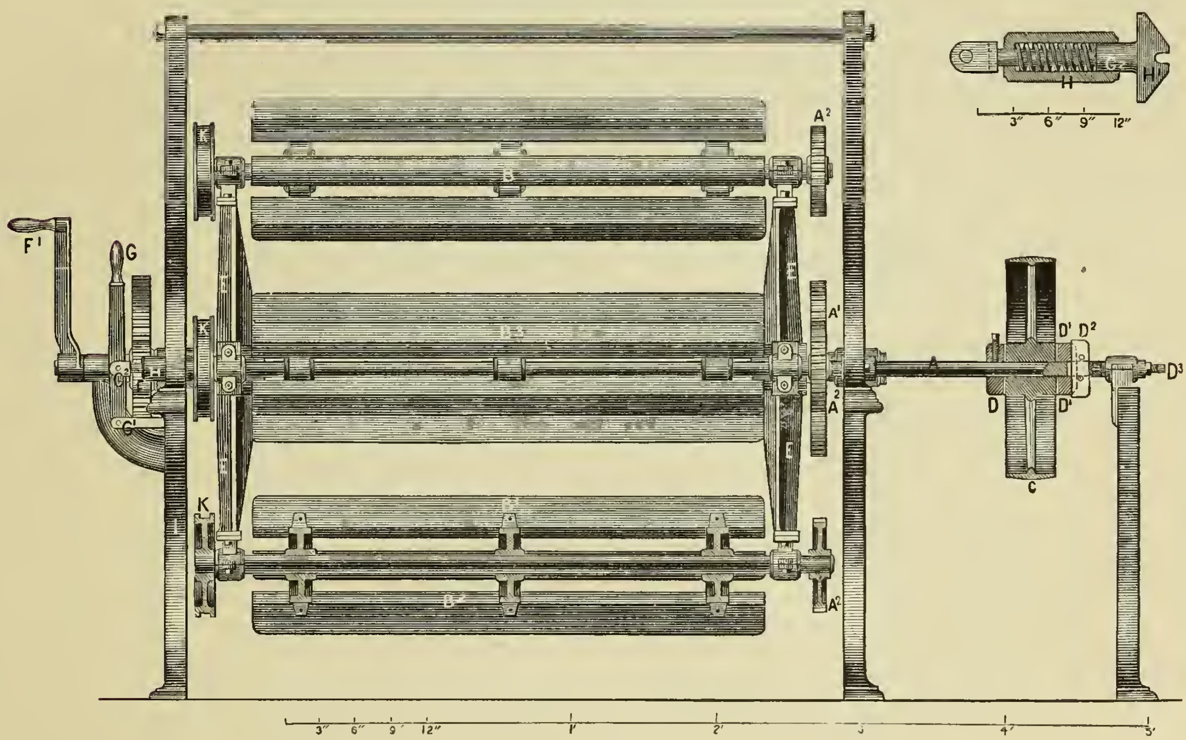
It is necessary to hold the reels, while working, stationary in the position represented in our drawing, and this is accomplished by means of the lever G, which

pivots in G', and by the bolt G^2 fastened to it with a pin. A section of this bolt G is shown on a larger scale in Fig. 74.

The casing H is fastened to the stand I, and in it rests the bolt G^2. The head H' of this bolt is notched out to fit the projecting rib of each of the arms E', and is forced to hold it in its grip by the pressure of the spiral spring in the casing H.

When it is necessary to move the reels round, the machine-tender pulls the lever G back, presses the spring together, and allows the arm E' to start off. He then leaves the lever G to itself again; the spring pushes the bolt G^2 forward until the next arm E arrives, and by its own motion fastens itself in the notch of the head H'.

Fig. 73. Fig. 74.



Every reel is provided on the front side with a pulley K, which is not shown on B' (Fig. 72) in order to leave the bearing wherein the reel shaft rests uncovered. While the paper is rolled off from B B^1 and B^2, it must be kept stiff or stretched; leather bands, carrying weights at one end and fastened at the other, are therefore laid over the pulleys K of such reels. The friction of the bands on the pulleys can be adjusted by means of the weights and the paper kept of the desired tension on its way to the cutter.

A section of the reel B^2 in Fig. 73 shows the iron spiders, the ends of which are tenoned and pinned into the wooden cappings which carry the paper.

153. Electricity.—The paper becomes strongly loaded with electricity by the friction on the heated dryers and in the calenders. It is often easy to draw sparks

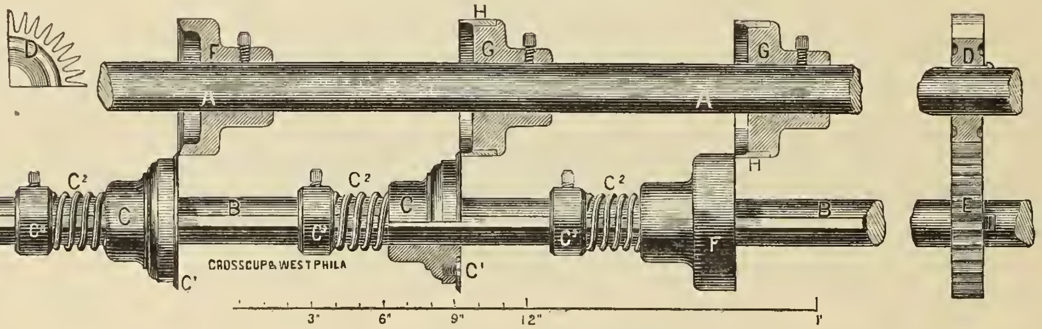
by simply bringing the fingers near it, and sometimes it gives trouble at the cutter by making the sheets stick together so closely that they can only with difficulty be separated.

A copper cylinder, of 2 to 3 feet diameter, connected by a wire with the soil, or, better, with a body of water, is in some mills interposed between the calenders and reels, the paper conducted over it, and relieved of its electric burden.

VIII. *Trimming and Cutting.*

154. Slitters.—The edges of the paper which has been wound up on the reels, after it has passed the dryers, are always rough, and must be trimmed. The sheets ordered by the consumers are seldom large enough to require the whole width of the paper, and the web is therefore cut lengthways into two or three parts by means of small circular knives called slitters.

Fig. 75.



One or two pairs of slitters must be provided for this purpose, in addition to those which trim the edges.

The shafts A and B, Fig. 75, represent those carrying the upper and lower slitters.

Slitters of the most generally known construction are shown in those marked C, as view and section. A steel ring-shaped plate C′ is fastened with screws to the cast-iron body C; it is from $\frac{1}{8}$ to $\frac{3}{8}$ inch thick and turned slightly concave, making a sharp edge at the circumference. Two of them on A and B running very fast, with their edges touching each other, will cut the paper like shears. The slitters on one shaft are fastened with set-screws, and those on the other slide freely, pressed against their mates by means of spiral springs C^2 and collars C^3. A key-seat is cut from end to end in both shafts A and B, so that the slitters and collars can be set in any place.

The edge of the steel plates C′ gradually wears down, and their diameter becomes smaller.

The lower shaft rests stationary on the frames, and is driven by a belt and pulley on the projecting end; but the upper one can be lowered a short distance, until the plates C′ overlap each other sufficiently.

The cogs of the driving pinions D and E must be very long to be able to follow the up and down movements of the upper shaft, and yet remain geared.

One quadrant of the pinion D, showing the form of the cogs, is drawn separately in our Fig. 75.

Several kinds of slitters, on which the diameter of the cutting edge remains always the same, have been constructed.

Some are made entirely of cast iron, turned conically on the edge like F, but they have to be frequently sharpened. To avoid this, a steel band H is shrunk on a cast-iron body G, and then turned out so thin that it remains self-sharpening until used up. It is, however, difficult to temper this steel ring, so that it will cut well without being brittle.

After prolonged and repeated use of these different slitters, the author preferred the old plate C′ on a cast-iron body C for ripping or separating the web into sheets, and retained F and G only to trim the edges.

But the advantage of F and G, that the distance between the two shafts can remain undisturbed, is lost as soon as one or two only of the plates C′ are put on. It is therefore preferable that one shaft should carry only one kind of slitters, and many paper-makers, after frequent trials with other constructions, have returned to the exclusive use of the old style C.

If the edges or plates of the upper and lower slitters touch each other at many points, they cannot cut as sharply as if they were pressed together only where they work. It has therefore been found of advantage to set the upper shaft a little out of square, in such a way that the edges which the paper meets first are alone in contact.

The deviation from the square line required for this purpose is so trifling, that the working of the spur-wheels will not suffer from it.

If the slitter-shafts are not strong and stiff, they will spring and make accurate cutting impossible.

The diameter of the slitter-shafts should be increased with the width of the machine—a 3 inch shaft being, for example, right for an 84 inch machine.

155. **Cutters.**—The action of the cutting-machine is an imitation of that of the knife, guided by hand.

The table, on which the paper is spread for the operation of the latter, is represented in the former by a stationary bed-knife; and while the sheets are passing over or resting on it, the movable knife begins to cut at one end, and gradually proceeds all across, like scissors.

The cutters may, according to their construction, be classed as continuous feed-cutters and stop-cutters.

On continuous feed-cutters, of which we know only one kind, the paper is moved forward without any check; it travels on while it is being cut off.

The reels deliver the paper continuously also to the stop-cutter, as long as it is in motion, but the web is prevented from proceeding between the knives; it stops while the cut is being made.

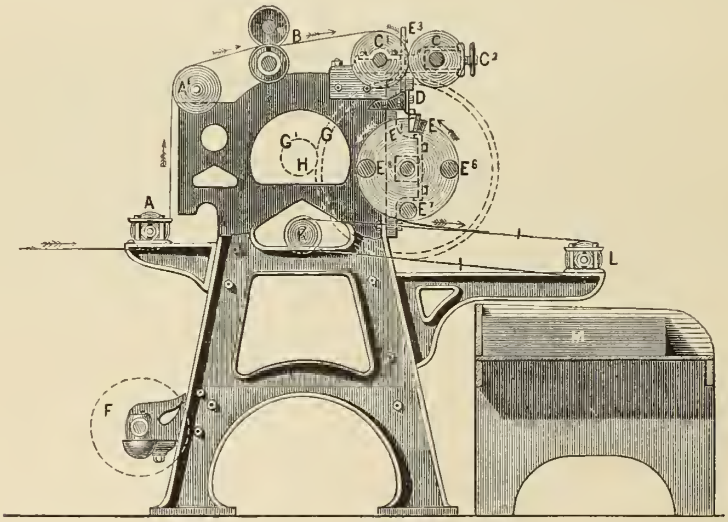
Of this latter kind, a great many different ones have been constructed; but we shall content ourselves with the description of the one which forms part of the machine represented on the plates, and of a later invention, which seems to deserve the attention of paper-makers.

156. Continuous Feed-Cutter.—A side and front elevation of Gavit's continuous feed-cutter are represented in Figs. 76 and 77. The upper part of the side elevation, Fig. 76, is shown as a section.

The paper coming from the reels moves in the direction of the arrows, over the rolls A A′, through the slitters B, the feed-rolls C C′, and over the bed-plate D, at the lower edge of which it is met by the revolving-knife E, and cut off.

The bed-knife D is parallel with the shafts or square to the frame, and the revolving-knife E must be fastened in E^2 E^2 so that it forms an angle with it; in

Fig. 76.



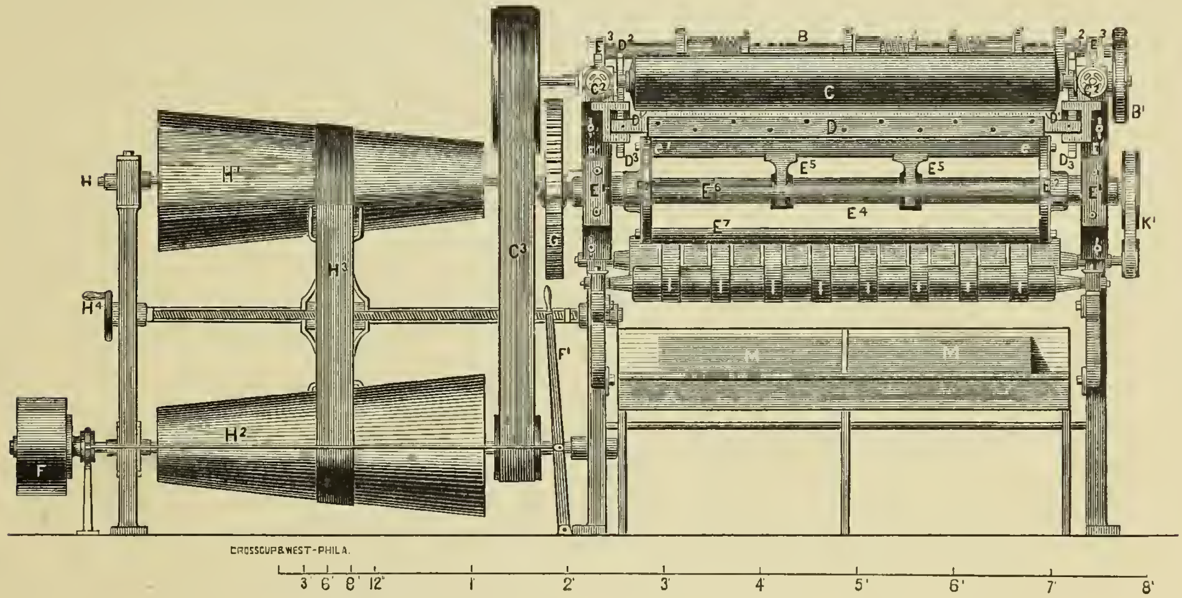
other words, one end *e* of the knife E must strike or rather pass D a short time before the other end *e′* reaches it. In this short time, during which the sheet is cut, the paper moves continuously on, and has passed some distance ahead of the bed-knife D at the end *e*, before E cuts the other end *e′*. If the knives were arranged so that the cutting edges would meet in a horizontal or level line, the sheets would not be cut square; they would, if folded up, show one corner considerably further out than the other. If, however, an inclined position is given to the knives; if the bed-knife D is set so that it descends from *e* to *e′* as much as the sheets would be out of square if the edge of D were horizontal, the cutting-knife meets and cuts the paper on a square line drawn from the point where the end *e* has made the first incision.

This deviation from the horizontal line, or the advance of the end *e′* beyond *e*, must be different for sheets of different lengths, respectively for different speeds of the

revolving-knife, and can be regulated by means of the set-screws E^3. The cast-iron bearings E', in which the revolving-knife rests, have a projecting extension, which carries the cast-iron body D', to which the steel bed-knife is fastened with screws. The set-screws E^3 are threaded into the cast-iron bearing common to the two feed-rolls C and C^1, and their lower ends rest on the upper parts of the two bearings E', either of which can be lowered or raised, and with it the two knives D and E. The bolt-holes, through which the bearings E' are attached to the stands or frames, are elongated perpendicularly, to permit of their being shifted up or down. The bed-plate D^1 does not merely rest on E', but its ends are held between two set-screws D^2 and D^3, by which the position of D relative to E can be adjusted.

The driving-pulley F is connected with its shaft by a coupling, which can be thrown in and out of gear by the lever F^1, and the cutter thus stopped and started. A

Fig. 77.



belt C^3 drives the feed-roll C^1 directly from the shaft of F; the paper is therefore fed with invariably the same speed so long as the general speed of the machine does not change, no matter of what length the sheets are to be cut.

The rolls C and C^1 must hold the paper with a firm grasp to pull it uniformly from the reel; they are of copper or wood, covered with felt, and C can be pressed against C^1 by means of two set-screws C^2. On wide machines these rolls should be very strong, to prevent them from springing in the middle. The felt-cover is frequently not rough enough to hold the paper tight, permits it to slip between the rolls C and C^1, and causes the sheets to be cut too short. A number of square diamond-shaped pieces of felt are therefore tacked or sewed on the surface of C, which act like so many fingers, and give to the roll an appearance similar to a chess-board, the

white fields being represented by the pieces of felt. Only the advance corner of these diamonds need be tacked or sewed on; the remaining parts may be loose.

A sheet is cut off as often as the shaft E^4 of the revolving-knife makes one revolution.

This shaft carries a spur-wheel G, which is geared with the pinion G^1 on shaft H, and through it moved by the wooden cone-pulleys H^1, H^2, and belt H^3. By turning the crank H^4 and the screw which shifts the belt H^3, the speed of shaft H and consequently of the revolving-knife E can be changed at will, and with it the length of the sheets. If the revolving-knife E runs faster, the sheets will be shorter; if it moves slower, they will be longer.

If the cones H^1 and H^2 are short and steep, a trifling change in the position of the belt will cause a considerable change in the length of the sheet; they can therefore be cut more precisely if the cones are long and less steep.

The revolving-knife is, like the bed-knife, a steel plate with a straight edge, screwed on a cast-iron body, which is fastened to the circular plates E^2, and supported by the arms E^5. It is sometimes necessary to spring out the knife E at or near the middle to make it cut at every point, and this can be done by driving keys between E and the arms E^5.

The duty of the brass tubes or wooden rolls E^6, E^7, E^8, is to prevent the sheets from falling straight down, and to carry them in the circle indicated by the arrows, until they reach the endless strips of felt I I running over the iron rolls K and L, which deliver them on the box or table M, where they are piled up, and assorted as much as possible by female attendants. The roll K is turned into high and low parts, in order to keep the strips I at the desired distance; it receives its motion through a belt K^1 from the shaft of the revolving-knife. The slitter-shaft is driven by a belt B^1 from the shaft of the feed-roll C^1.

The cone-pulleys H^1 and H^2, with stand and belt, occupy, as shown in our drawing, a space of nearly the same size as the cutter itself. This space may be saved, and longer—consequently flatter—pulleys than those represented used, if they are placed right under the cutter, resting on the frames, both at the same height above the floor.

The theory, on which the construction of these cutters is based, is apparently quite correct, but, though many are in practical operation, few paper-makers succeed in cutting square sheets with them.

Its many other good qualities and the fact that, with careful management, it can be made to cut near enough square for many kinds of paper, have made it a favorite with many manufacturers.

The difficulty of cutting square sheets is caused by the double adjustment of the knives, which is necessary whenever the length of the sheet is changed.

We will suppose that the knives have been properly adjusted, and are cutting sheets of a certain length and breadth square and correct, and that we desire to change the length of the sheet a few inches. The belt on the cone-pulleys must be

shifted first until the sheets are of the desired length, when they will in most cases be found not to be perfectly square, and to remedy this, either the end *e* or *e′* must be raised or lowered a little. Though the revolving and bed-knives are supported by the same bearings E^1, it is often found that they will not cut entirely across the sheet whenever one of these bearings has been moved up or down.

The bearings E^1 are only slotted out perpendicularly to allow them to move up and down while the bolts which fasten them to the frames remain in their places, but there is no provision made to permit of a movement sideways.

If we consider the bearings E^1 with the two knives as a solid, unchangeable, oblong frame, which it ought to be, it is evident that its two lower corners, or the lower ends of E^1, will move sideways a very short distance, if they be allowed to do so, whenever one of the upper corners alone is moved up or down. But no provision being made for this movement, the long sides of the oblong frame or the knives are bent or sprung and will not cut; the machine-tender alters their relative positions by means of the set-screws D^2 and D^3, to remedy the evil, then turns the set-screws E^3 again, and keeps on trying and altering until he is perfectly satisfied if the knives will cut at all, even if the sheets are not square.

If the bearings E^1 are suspended in the bolts at the upper end, so that the moving upper and both lower corners can freely swing sideways while one side is lowered or raised, if all the bolts are loosened while this is done, and if the machine-tender understands the principle of the movement, there should be no necessity for changing the relative positions of the two knives, or of ever touching the set-screws D^2 and D^3, except when the bed-knife must be taken out to be sharpened or replaced by a sharp one.

The cause of difficulties may sometimes be found in the manner in which the cutter has been built. The shafts may not be strong enough and may spring, the frames may not be solid, or the working parts may not be finished with sufficient care.

If very long sheets are cut, if they are thin, pliable, and considerably longer than the circumference (usually 36 inches) of the revolving frame, to which the knife E is fastened, they move faster than the circumference, and being thrown against the rods E^6 E^7 E^8, are retarded by the contact with the slower revolving frame, bend into it, and are carried round a second time, cut again, and spoiled. The revolving frame should be of a larger diameter for such sheets.

The difficulties experienced with this cutter in cutting square sheets of different lengths have caused the invention of improvements, by means of which they can be overcome.

157. Fletcher's Improvement.—Mr. Frank A. Fletcher, of Newark, Del., has received a patent, November 28, 1871, for a device of this kind.

The following Fig. 78 and Fig. 79 show his invention in section and front elevation. y y^1 are flexible metallic plates bent along the line z z^1; one for every sheet is fastened to the bed-knife D, and the lower portion y^1 is bent up in the manner

shown in the section. The paper, going in the direction indicated by the arrow, descends between the feed-rolls C C^1, travels at one end over the bulged-out portion y^1 of the elastic plate, and reaches the revolving knife E later than if it only passed over the straight plate, as it does at the other end. The plate y^1 must be bent up more for long and less for short sheets; the exact position is soon found by experiment. The metallic (copper) plate may also be cut through on the line z z^1, both parts joined together with hinges z^1 at the lower end, and by a strip of sheet lead H at the upper projecting end. This strip x is fastened by the screw x^1 and soldered to y^1; it is stiff enough to hold y^1 in any position, while it can at the same time be easily bent.

Mr. Fletcher uses a separate regulating plate y y^1 for every web or train of

FIG. 78.

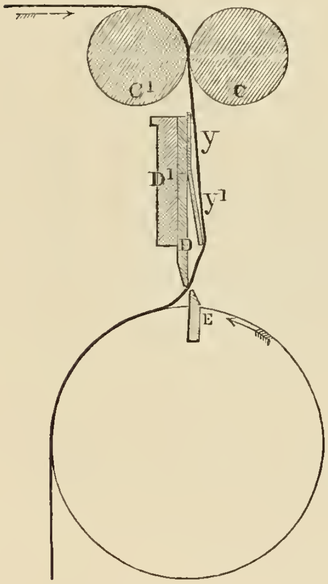
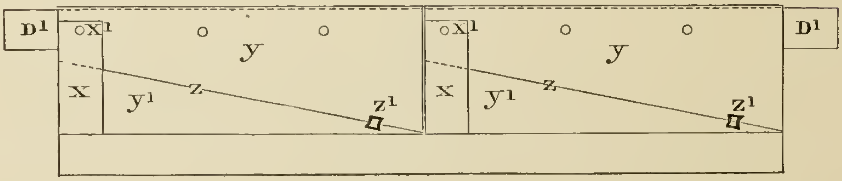


FIG. 79.



sheets that is to be cut, because the projecting end would have to stand out twice as far from the bed-knife D if it served for two sheets, as it would if serving for one only.

At the lower end of the line z z^1, where the knives begin to cut the sheet, the plate y y^1 is flat, and the paper comes from the feed-rolls C C^1 in a straight route; but as the knife E continues to cut towards the other end, the increasing projection of y^1 forces the sheets to travel round it, and thus retards the arrival of the square line on which they are to be cut until it is met by the knife E.

When the knives are once set so that they will cut through, they can, by this attachment, be made to cut square for different lengths of the sheets without changing their position. From personal observation we can state that the sheets cut in this way leave nothing to be desired.

158. The Dog-Cutter.—A stop-cutter of this name, which it has been given by paper-makers for the better distinction from other stop-cutters, is represented by elevations, showing it as seen from the tending and driving sides in Figs. 80 and 81.

The front view (Fig. 80) shows the line on which the paper passes to the knives. It is pressed to the felt-covered, wooden feed-roll A by the weight of the three wooden rolls B B¹ B², the bearings of which form one piece of casting, bolted to the frames on each side. The frames are slotted out to allow the adjustment of this casting.

The revolving-knife is carried by a solid cylindric casting C, to a projection of which it is fastened. This projection extends over one-fourth of the circumference of C; it starts at one end, and winds its way across in a spiral line until it reaches the other end, a quarter of a turn later. The screws with which the thin steel knife is fastened to this projection are so numerous that they force it to adapt itself to the form of the casting.

The horizontal bed-knife D is fastened on an upright cast frame D^3, which turns slightly on hinges D^1, and thus yields to the pressure of a spiral spring on a screw-bolt D^2, supported in the solid stand D^4, whereby the bed-knife D is pushed against the revolving-knife. One such hinge and spring arrangement is bolted to the frame on each side, and the latter is slotted out to permit it to be shifted sideways.

The ends of the casting, which forms the immediate support of the bed-knife D, are fastened to D^3. A part of the frame is broken out in the drawing, so that the bed-knife D may be seen.

The revolving-knife is filed down a little (about $\frac{1}{16}$ to $\frac{1}{8}$ inch) at the end, where it strikes the bed-knife first, but recovers its original size a few inches from the end. It thus pushes the bed-knife D gradually back $\frac{1}{16}$ to $\frac{1}{8}$ inch, and fits to it closer and neater than it could if the corner which first touches projected as much as the following parts.

By tightening or loosening the spiral springs the bed-knife can be pressed more or less against the revolving-knife.

While the feed-roll is stopped the paper continues to come from the reels, and is held in tension by the weight of the wooden roll E, the journals of which slide up and down in the frames E^1.

Between the slitters F and the feed-roll A, the paper is carried over a wooden board G supported by brackets fastened to the frame. The board must be covered with zinc or copper, and offer a smooth surface to the paper. A similar zinc or copper-covered wooden support G^1 is given to the paper before it enters the slitters.

The pulley H^1 on the lower slitter-shaft is driven from the pulley H on the feed-roll shaft.

The whole cutter is driven from the shaft I (Fig. 81), which receives its motion from the line shafting and pulley I^1.

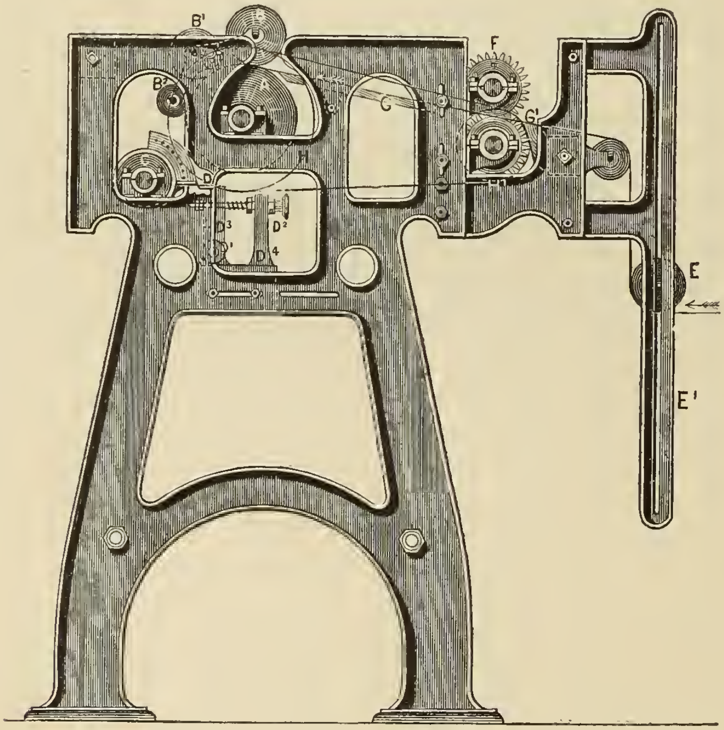
The spur-wheels K and K^2, mounted respectively on I and on the shaft of the revolving-knife, are of equal size and connected by an intermediate wheel K^1; their shafts make therefore the same number of revolutions, or K^2 turns once, and the revolving-knife makes one cut for every revolution of the pulley I^1.

The spur-wheel A^1, on the feed-roll shaft, has 36 cogs, and is moved by the cogs of the wheel L; the feed-roll A is of 9 inches diameter or 28.25 inches circumference. With every revolution of the feed-roll or of A^1, 28.25 inches of paper pass through the cutter, or $\frac{28}{36} = \frac{7}{9}$ inch for every cog.

A sheet is cut whenever the revolving-knife or the shaft I accomplishes one revolution, and its length is determined by that which the feed-roll A supplies. If the wheel A^1 is, for instance, turned one and a half times, or as far as $36 + 18$ or 54 cogs while the shaft I turns once, the length of the sheet will be $54 \times \frac{7}{9} = 42$ inches. The driving-wheel L must therefore be supplied with 54 cogs for sheets of that length.

Segments of 2, 3, 4, 5, and more cogs must be on hand, which can be screwed to the face of the pulley L to compose any desired number; and they must occupy

FIG. 80.



such a position that the knife begins to cut, shortly after all the cogs on L have passed those of A^1; that is, as soon as the feed-roll A stops.

The feed-roll A would not stop suddenly enough, if some kind of brake were not applied to it. A wheel M, which is notched out all round to receive the dog O, is therefore mounted on its shaft.

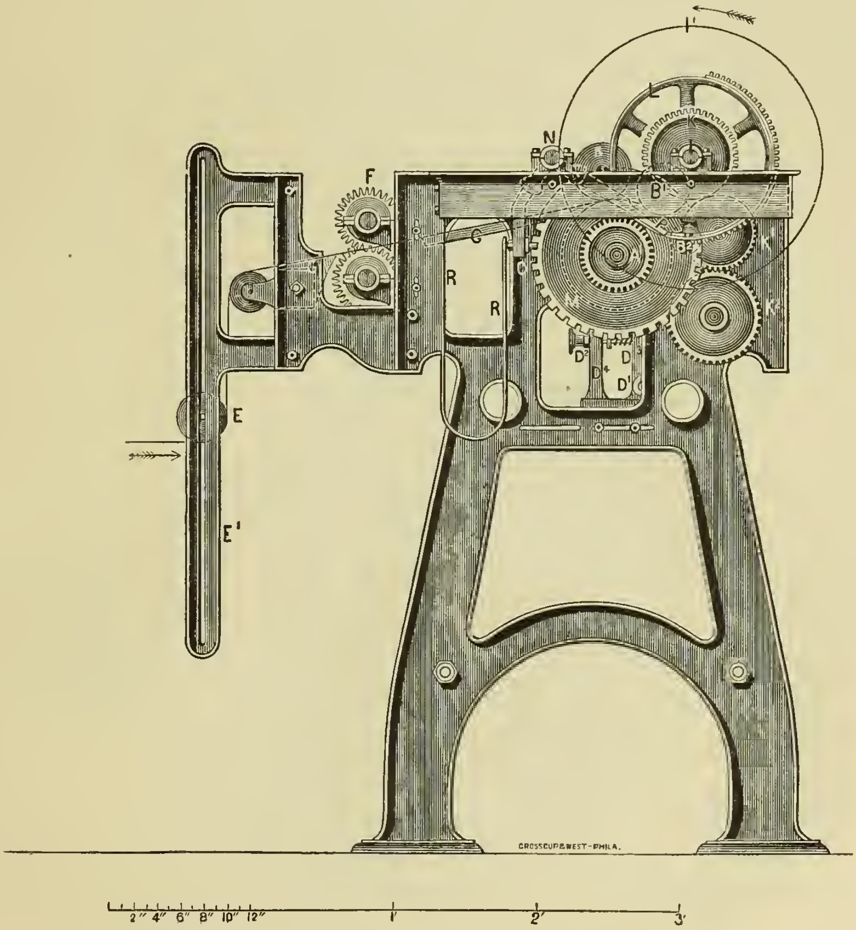
A bearing N carries a short shaft with an angular casting, which ends in the arm and point O and in the lever P.

The cogs, which are fastened on L, have on one side a projecting flange, on

which the lever P rests, as long as the cogs are in contact with those of A^1. As soon as they have passed through, P loses its support, and O, being pressed against M by the iron spring R, falls into one of the cavities or notches, and thereby stops the feed-roll effectually. As soon as the cogs on L meet those on A^1 and their flanges touch P again, the latter is forced out, and with it is the dog O lifted off of M, and the feed-roll allowed to start.

The wheel M must be stopped with precision, and it is necessary that a strong pressure should be brought to bear on O.

Fig. 81.



A strip of a sound hickory plank is sometimes fastened on to the floor, and to the frame, half way between the floor and O, while its free upper end presses on O, in place of the iron spring R.

Since the addition of one cog on L increases the length of the sheets $\frac{7}{9}$ inch, no change can be made by these means of less than $\frac{7}{9}$ inch. This is sufficient in most cases; but if a smaller variation be required, it can be produced by increasing the

diameter of the feed-roll A. Felt or paper can be wound round it for this purpose until the sheets have the desired length.

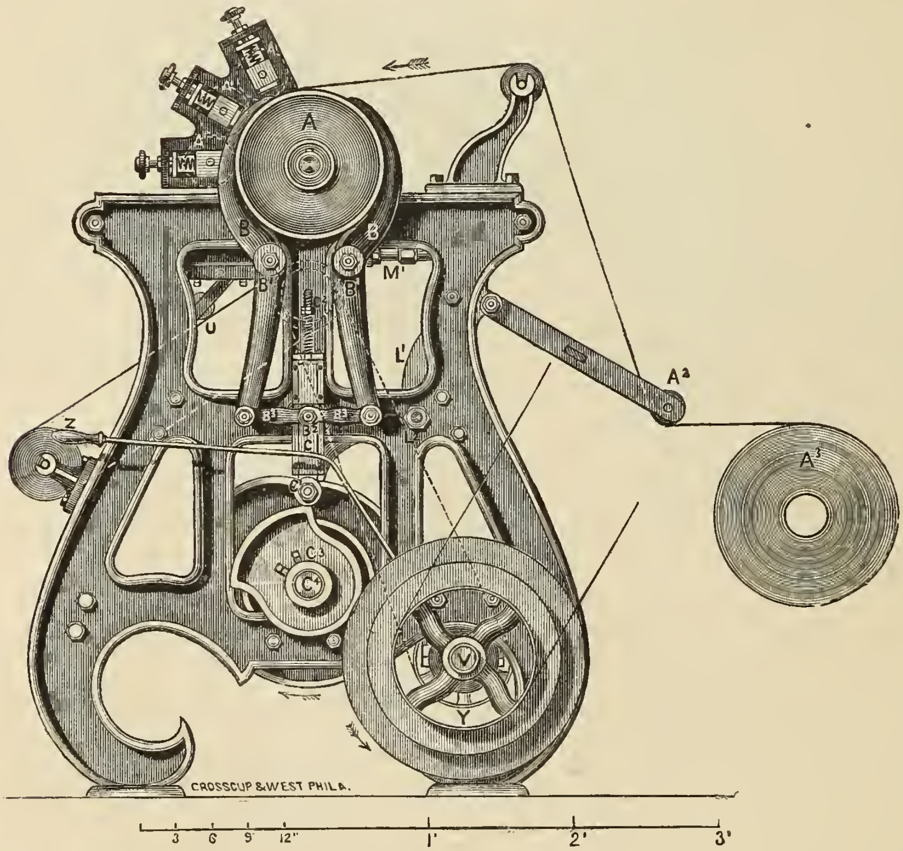
The table extends under the cutter some distance, and the paper, on leaving the knives, drops down on it, and is spread out and sorted by the cutter-girls.

This cutter gives perfect satisfaction in many mills; it cuts square and is of simple construction. Its defects, if they can be called such, are: that no change in the length of the sheets can be conveniently made of less than $\frac{7}{9}$ inch, and the noise made by the dog when falling in and stopping the wheel M.

159. Hammond's Cutter.—Mr. George W. Hammond, manager of Messrs. S. D. Warren & Co.'s Cumberland Mills, near Portland, Maine, owns the patent for a cutter, granted to John E. Coffin, January 3d, 1871.

The following Fig. 82 is an elevation showing the back or driving side, and Fig.

Fig. 82.



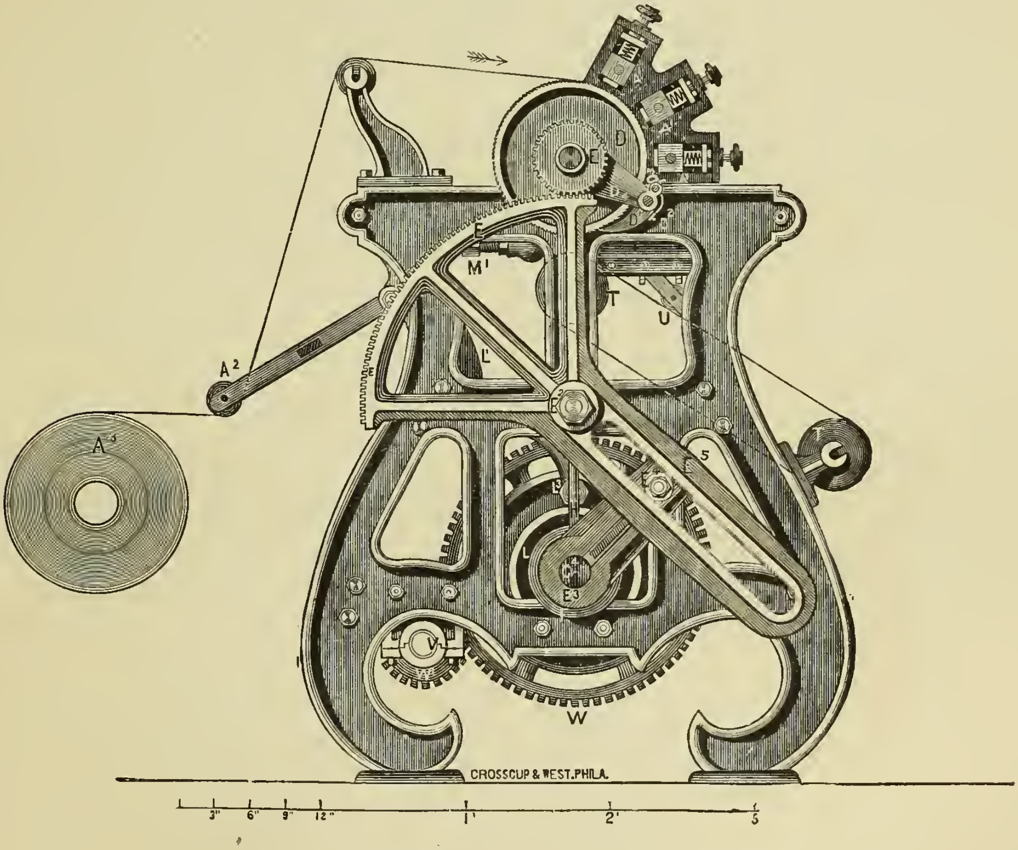
83 is an elevation showing the front side. The drawings are an exact representation of the cutters in operation at Cumberland Mills.

The paper is conducted to the feed-roll A (Fig. 82) in the direction shown by the arrows. This feed-roll A is a large iron drum, against which the paper is pressed by means of three wooden rolls A^1, the bearings of which are operated on by screws

and springs. Wooden rolls, if made of one piece, frequently become warped; the feed-rolls A^1, as constructed by Mr. Hammond, are therefore composed of two pieces, or split in half, glued together again, and held inseparably connected by iron rings on the ends. It is claimed for the iron drum A that it removes the electricity from the paper. The movement of this drum and of the paper on it must be stopped while a sheet is being cut off; but as the reel will roll off some paper even after the feed-roll has stopped, the web must be kept in tension by the weight of the roll A^2, which rests freely on it.

The movement of the brake B, which operates on the elongation of the drum A, causes it to stop and start suddenly. The two arms of this brake B turn in the bolts B^1, and their levers B^3 B^3 are joined together by the bolt B^2, which moves both. As long as the two levers B^3 form a straight line, the brake B grasps and stops the drum A;

Fig. 83.



but a slight deviation from this line, or a downward movement of the bolt B^2, opens the brake again and allows the drum to start. The bolt B^2 is fastened to a flat, straight piece of iron C, which has a roll C^1 attached to its lower end, and is guided or incased in a close-fitting box. This box is open so far as the movement of the bolt B^2 requires it, but is covered on the rest of its face. A bolt, carrying a nut C^2, is con-

nected with the upper end of the traveller C, and a spiral spring, the ends of which are fastened to the nut C^2 and to the top of the guiding-box, pulls the nut C^2 and with it C and the roll C^1 downward.

One quadrant of the eccentric plate C^3, on which C^1 rests, is elevated above, or has a larger diameter than the other three, and while it is in contact with C^1, or during one-fourth of its revolution, the levers B^3 are kept in a straight line, the brake grasps the drum A, and the paper stops. As soon as C^1 descends on to the narrower circle of C^3, forced down by the spiral spring, the bolt B^2 descends with it, and the brake B releases the feed-roll during three-quarters of each revolution.

Sheets of equal length cannot be cut unless the feed-roll stops and starts, or the brake opens and closes exactly on time; the descent from the elevated to the lower part of the plate C^3 is therefore steep and abrupt.

The ratchet-wheel D, fastened on the shaft of the feed-drum A on the front side of the machine, is turned round by the ratchet or pawl D^1, which is closely connected with the pinion E^1. A spring, which is fastened on the pawl D^1 with a screw D^2, and rests with the other end on a pin D^3, presses the ratchet constantly against the wheel D.

The ratchet must be at work and push the wheel D, and with it the drum A, forward while the brake B is open; but during one-quarter of the revolution of the shaft C^4, while the drum A stops, the ratchet D^1 must return to its original position, or travel as far back as it had advanced during the other three-quarters of the revolution.

This is accomplished by the quadrant E, which moves the pinion E^1, and has its turning-point in the bolt E^2. The roll E^4, movable on a screw carried by the crank E^3, is placed in a sleeve E^5, which forms the elongation of the quadrant E.

The quadrant E is turned as far as possible to either side, or has reached its two extreme positions, when the crank E^3 and the sleeve E^5 form a right angle or square. Our drawing (Fig. 83) shows one of these positions, and the other will be reached as soon as the shaft C^4 has made one-fourth of a turn. During this quarter of a revolution, or while the feed-drum A is stopped, the quadrant E turns the pinion E^1 and ratchet D^1 backward as far as they had been advanced during the other three-quarters of the revolution, made by the shaft C^4.

The length of the sheet depends on the quantity of paper which is delivered to the knives by the feed-drum A during one, or rather three-quarters of one, revolution of C^4. This again depends on the number of turns which the pinion E^1 makes during that time, or on the number of cogs of the quadrant E which come in contact with it. All the teeth of the quadrant come in contact with E, or the longest possible sheet is cut, while the roll E^4 occupies the position shown in our drawing. If the roll E^4 is moved in towards C^4 on the screw which carries it, the throw is shortened, only a portion of the cogs of the quadrant E come in contact with the pinion E^1; the latter, and with it the feed-roll, turns less, and the sheets will be shorter.

Every revolution of the pinion E furnishes a sheet, as long as the circumference of the drum A; and from this we can calculate what difference in the length of the

sheet one cog more or less of the quadrant E will produce. A short experience will teach any one how to adjust the nut or roll E^4 so that a sheet of the desired length will be cut.

The ratchet-wheel D can, however, be moved forward only a certain number of full cogs; it cannot be advanced as little as a fraction of a cog. The cutters of this kind which are at present in use admit thus of a change of one or many quarters of an inch in length, but not of any smaller variations. This is, however, sufficient for the usual demands of the trade.

If the ratchet D^1 were allowed to rest on the cogs of the wheel D, while it makes its return movement, it would make a disagreeable noise; the inventor has therefore added the following arrangement, shown as side and front elevation in Figs. 84 and 85, by which the ratchet D^1 is raised up during that time.

The frame G of the cutter has a projecting bracket on the front side, which carries a lever H, turning on a bolt G^1; the upper end of this lever is a fork H^2, which clamps or holds the conical plate I on the feed-roll shaft. The spiral spring H^3, in a stretched condition, connects the frame G with the lever H, pulling the upper end back against the frame, and pushing the lower end, the roll H^1, against the plate F. This plate F has an elevation F^1 on one-quarter of its circle, which, when in contact with H^1 (while the brake holds the feed-drum A), pushes the conical plate I at the upper end of the lever H towards the ratchet-wheel D, thereby lifts the dog K as high as the larger diameter or circumference of I, and thus raises the ratchet D^1, with which K is connected, from the wheel D.

Fig. 84.

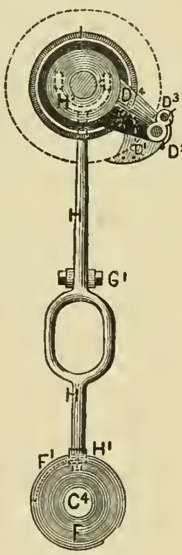
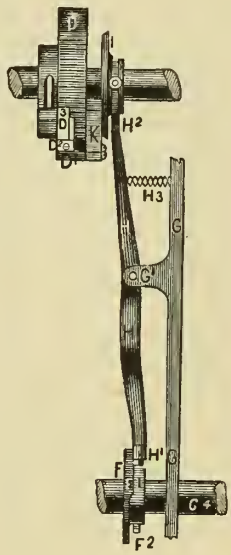


Fig. 85.



The disposition and movement of the knives are shown in sectional front and side elevation by Fig. 86 and Fig. 87.

The cutting-knife moves horizontally, and is propelled by two eccentric plates L on the shaft C^4, situated close to the frame on each side. These plates L are circular for three-quarters of the turn, and for the other quarter rise high enough to pull the levers M back and forward by means of the little rolls L^3, which form the lower end of the levers L^1. These levers L^1 turn on the fixed points L^2, and are connected with M by means of bolts M^1, which can be lengthened and shortened.

The plates L are shaped so that the cut is made, and the knife returned to its original position, during one-quarter of a turn of C^4, or while the drum A stops.

The casting N is fastened on to the two levers M, and the steel cutting-knife O is screwed to it in such a position that it will cut like shears.

The bed-knife P is fastened on the plate P^1. The set-screws N' and N'' work or

rest against plates, between which the levers M are sliding; these levers M, and with them the knife O, can thus be slightly moved up or down and adjusted.

A sheet of tin S is fastened to a square piece of wood R, which is situated in front of the knife P, and guides the paper so that it cannot fail to pass between the knives. The cut sheets are forwarded to the table or box by endless strips of felt running over the rolls T T, and held down on these strips by the weight of the roll U.

Three pulleys, by which three different speeds can be given to the cutter, are keyed on to the shaft V (Figs. 82 and 83) besides the pinion W′, which drives the spur-wheel W, and through it the shaft C^4, and besides the pulley Y, which sets the upper one of the rolls T T in motion. A coupling connects the driving and driven parts of the shaft V, and is put in and out of gear by the lever Z.

Fig. 86.

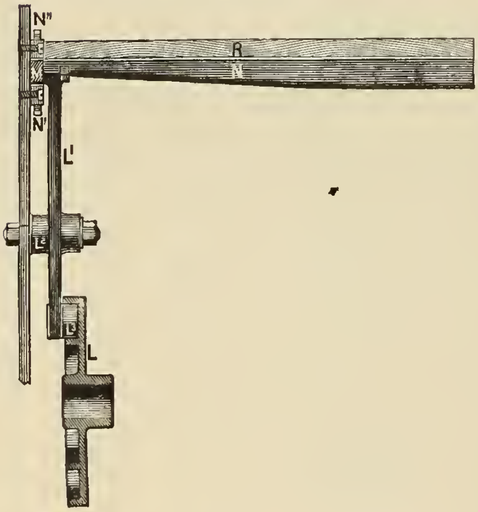
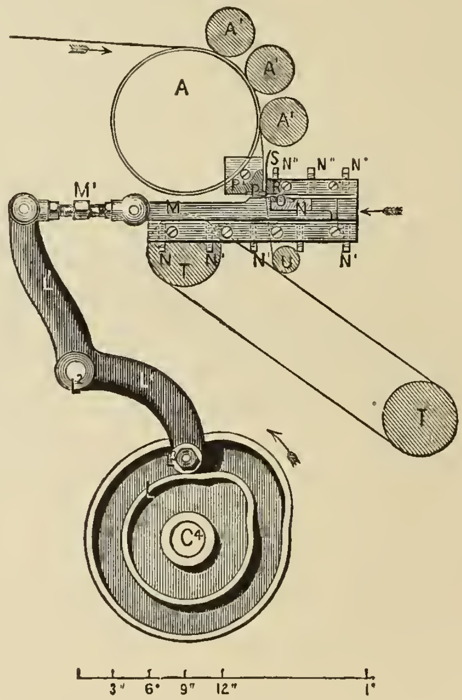


Fig. 87.



This cutter is of very solid construction; its knife cuts horizontally, the length of the sheets is easily regulated, and it has the advantage over many other ones that it works without any noise.

160. Selection of a Cutter—Cutter-Table.—In the selection of a cutter the preference should be given to the one which, with the smallest amount of machinery or the simplest construction, gives the best results.

The paper is usually received from the cutter by female attendants, one for each train of sheets, and laid in piles on a table. While this is being done, they are carefully inspected, and defective sheets are taken out.

To save the labor of one or two girls, a *lay-boy* is sometimes used, which takes

the paper, and piles it up automatically, with only one boy or girl to watch it. This will do very well for good qualities of paper, which do not require much sorting; but if the paper breaks often and requires a more careful examination, it will be of advantage to have a larger number of eyes and hands on it, and then a girl for every train of sheets is preferable.

It is necessary that the sheets should be laid or piled up evenly, so that the edges form perpendicular lines, or, in other words, that every sheet should cover the preceding one perfectly.

The table must therefore have two square sides, which serve as guides for the sheets.

If printing paper is being made, it is taken by the finisher from the columns which have been formed of the packages accumulated on the table, and at once counted and folded.

Unless the sheets are laid so that they cover each other, and are piled up straight, they will not be folded exactly in the middle, as the finisher has no time to straighten them, and the quires will then present an irregular appearance.

A cutter girl, who does not understand her business, may cause much trouble in this way as well as by not throwing out defective sheets.

161. Paper in Endless Rolls.—The paper is for many purposes required in rolls instead of sheets; for instance, for hanging, roofing, manilla bag paper, and for some printing presses. In such cases it is conducted through the feed-rolls of the cutter, all other parts of which are at rest, or if no cutter is supplied to the machine, directly from the slitters to a shaft, which is turned by friction like the driving shaft of a reel, and wound up on it.

If it were rolled directly around the shaft, the paper-rolls would fit on it so tightly that they could not afterwards easily be removed. The shaft has therefore a key-seat all along, and into it is placed a thick wooden or iron key-shaped rod, which projects considerably above the surface, and has a handle by which it can be pulled out. The paper is thus forced to form a larger circle on the shaft than its circumference, and the rolls can easily be slipped off as soon as the key is withdrawn.

Seth Wheeler proposes in the specification of his patent of July 25, 1871, not to cut the lower grades of paper, such as wrapping, &c., into sheets, but to punch rows of little holes across the lines where they are to be separated.

They could thus be easily torn apart, like postage stamps, and might be wound up and shipped in rolls, saving thereby the expense of labor and material for counting, folding, and packing.

Motive Power, Gearing, and the Machine-Room.

162. Motive Power.—The paper-machine must always be driven by a motor of its own, which furnishes power for it, the stuff-pump, and stuff-chest only.

It is of the greatest importance that the speed of the machine should be regular, as every part of it is set and arranged for the production of a certain quantity of paper per minute. The valves which admit water to the mixing-box, steam to the dryers, and draw water from the suction-boxes, are opened for a certain speed. The relative speeds of the different parts of the machine are also adjusted for it, and as all this cannot be quickly altered with every change of movement produced by an irregular motor, the paper will either break or show defects of some kind.

If the engines, rag-cutters, rotaries, or super-calenders were driven by the same motor as the machine, the stopping or starting of one of them would reduce or increase the amount of power which moves the machine, and cause a corresponding increase or reduction of speed. Even the best of governors cannot regulate promptly enough to avoid a serious derangement.

If water power is the motor, its independence should extend even to the water-supply. If one forebay is used for the wheels which drive the mill, as well as the machine, the starting of the mill, or of a beater only, will cause a sudden demand for more water, which may lower for a short time the head common to both ; the machine wheel will lose power, and its speed become reduced. The water-wheel, which drives the machine, should have a forebay and penstock, independent of any other one, and be fed directly from the race.

If the mill has an insufficient water-power, the paper-machine should be driven by a separate steam-engine. Referring to a subsequent chapter on steam-engines for more information, it may be stated here that the engine must be selected with a view to regular speed, and that a quick-acting, reliable governor is indispensable.

High-pressure engines are the most suitable, because the paper-machine furnishes in the drying cylinders an excellent condenser. The steam from the boilers is to be conducted to the engine through as large and short pipes as possible, rather too large than too small, so that nearly the full pressure may be available in the cylinder. After the steam has acted in the engine, and transmitted the larger part of its power to the piston, it escapes at a low pressure through short and capacious pipes into the drying cylinders, in which the exhausted steam is utilized.

The general experience is, that it takes but little more fuel to drive the machine and dry the paper with one stream of live steam, than for drying the paper only.

The following universally accepted theory gives a scientific explanation for this fact:

Boiling water and steam of the pressure of our atmosphere have both a temperature of 212 degrees Fahrenheit, and nevertheless considerable time and the continued application of heat are required for the transformation of the former into the

latter. The heat which has been expended during this time on the water, though it has not raised its temperature 1 degree and is apparently lost, is treasured up by it and is called "latent heat."

Before boiling water can change its liquid state into that of steam, it must have taken up a large amount of this latent heat.

In order to measure it, a unit has been established, which consists in the quantity of heat which is necessary to raise the temperature of 1 kilogram of water 1 degree of the Centigrade thermometer [100 degrees Centigrade are equal to 212 degrees Fahrenheit] under the pressure of one atmosphere or 14.7 pounds to the square inch. According to Regnault, $606.5 + 0.305\ t$ gives the number of units which are required to transform freezing water (of 0 degrees Centigrade) into steam of t Centigrade. For steam of the pressure of the atmosphere: t is the boiling-point or 100 degrees Centigrade, and $606.5 + 0.305 \times 100 = 637$ units are its latent heat. This steam, which has consumed 637 heat-units to overcome the cohesion of the water, has only a pressure of 14.7 pounds, and a temperature of 100 degrees Centigrade or 212 degrees Fahrenheit.

A comparatively trifling amount of heat is required to raise this steam to a higher temperature and pressure. Steam of five atmospheres pressure, for example, has a temperature of about 150 degrees Centigrade, and according to our formula absorbs

$$606.5 + 0.305 \times 150 = 652.2 \text{ heat-units}$$

for its formation from freezing water, or only 15 units more than steam of one atmosphere pressure.

It is evident from this that steam which is allowed to escape into the air, after it has been used in the engine, carries with it nearly all the latent heat, or over 600 heat-units. This is by far the larger portion of all the absorbed heat; the balance, which has been utilized in the engine, being only a small part—some writers put it at less than one-tenth—of the heat produced by the consumption of the fuel.

When steam is condensing, all this latent heat is set free again and delivered to the surrounding objects of a lower temperature.

Steam loses in the dryers, first, its temperature above 212 degrees Fahrenheit, and then the latent heat; but, since the latter is inherent in steam of any pressure and so overwhelmingly the larger portion, live steam cannot dry a great deal more paper than a similar quantity of exhausted steam.

Steam of high pressure has also a stronger tendency to rush through the cylinders without being exhausted than that which has been previously expanded.

A good governor permits the passage to the engine of just the amount of steam which is necessary to produce a certain power, and thereby becomes also a perfect regulator for the supply of steam to the dryers. If the speed of the engine and machine are increased, a larger quantity of steam is not only required for the engine, but also for the increased amount of paper which is to be dried.

Every steam-engine in a paper-mill should be built larger than at first required,

because, in the course of time, it is almost invariably burdened with more work than it was originally intended for. It will probably be expected to run the paper-machine faster and make more paper every succeeding year; and if the exhausted steam is used in the dryers, as it should be, it will offer some resistance to the piston, and a larger engine than might otherwise be necessary should be used on that account.

A steam cylinder of from 8 to 12 inches diameter, 16 to 24 inches stroke, and 60 to 80 revolutions per minute, according to the size of the machine, number of screens, calenders, stuff-chests, &c., will be sufficient.

The machine-tender should have the engine under his control; and it is therefore often located inside of the machine-room.

The engine sometimes consumes more steam than the dryers can use, and the surplus must either be allowed to escape or be utilized. The waste or escape-pipe therefore branches off in two directions: one leading to the dryers, and the other to any point outside of the building.

The latter branch is provided with a safety-valve, through which the steam must make its way. It must be regulated so that no steam can escape so long as the dryers have not been supplied with a quantity sufficient to dry the paper.

To reduce the counter-pressure on the piston as much as possible, all the pipes through which the exhausted steam passes must be very large—of at least 1 inch more diameter than those through which the engine is supplied with live steam—the larger the better. The openings through the journals and the pipes leading to them are usually too small, and cause a loss of power and fuel.

163. Gearing.—Figs. 1, 2, 3, Plate IV, represent a section, a front elevation, and a plan of the paper-machine, the details of which are shown on the previous plates.

A A are two pulp-dressers; B, a chest; C, the wire; D, couch-rolls; E and F, first and second press; G, dryers; H and H′, stacks of calenders; I, reels; K, a dog-cutter.

The whole machine is driven by a shaft L, which, by means of spur-wheels, connects with an intermediate shaft M, and from it, by another set of spur-wheels, drives the second press. The first and second press require a considerable amount of power, and, being usually close to the main shaft, they are often both driven by spur-wheels. In the machine represented on Plate IV, the first press, the couchers, the dryers, and the calenders are driven with belts directly from pulleys on the shaft M; but the seven dryers are divided into two lots of three and four, one of which is geared directly with the shaft G^1, and the other with the counter-shaft G^2.

The cutter stops and starts while the machine is running, and reacts with every stop or start on the shaft from which it is directly driven. If the cutter-shaft be connected with one of the calender-shafts, as is sometimes the case, and it stops suddenly, all the power which it has heretofore consumed is for the moment transferred to the calenders, until this surplus power or increased speed reaches, on its way back, the engine or water-wheel, and is reduced by the governor. The sudden reaction has, however, acted meanwhile like a blow upon the calenders, and perhaps broken the paper. If it be necessary, as in most cases, that the cutter should be driven by the

same motor as the rest of the machine, the connection with it should be as direct as possible. In our drawing, the cutter and reels receive their motion directly from the shaft L, transferred to them through the counter-shaft L^1. The screen-shafts A^1 and A^2 are moved in the same way by means of a counter-shaft L^2; and the shake-shaft C, the fan-pump C″, and felt-washer E receive their movement directly and indirectly from the screen-shaft A^1.

Care should be taken in the disposition of the driving part of a paper-machine to permit of an easy approach to all its parts. All that is said in a later chapter on gearings and belts applies here.

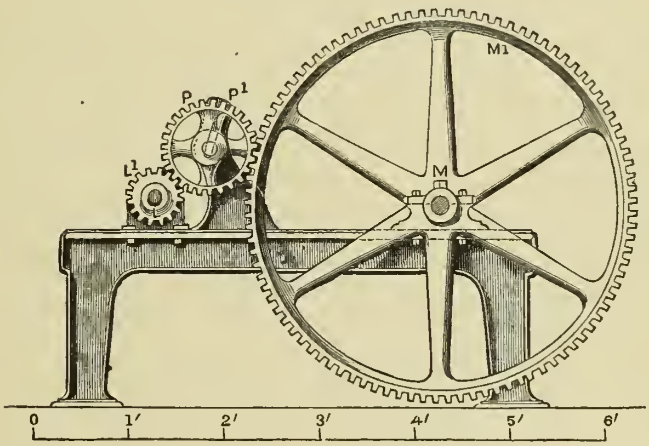
164. Change of Speed.—The machine must run slowly if a heavy paper is to be made, and fast if it is to be light; means to change the speed without altering that of the motor must therefore be provided.

The machine represented on Plate IV stands on the second floor, and below that floor are located a pair of large cone-pulleys, through which the motor transmits its power to the machine. Changes in the speed of the machine can be made by simply shifting the belt on these pulleys.

In many mills the shafts L and M are supplied with several sets of spur-wheels, which give as many different speeds.

A simpler and less expensive system is represented by the front elevation, Fig. 88. An intermediate pinion P is inserted between the driving-pinion L^1 on shaft

FIG. 88.



L and the spur-wheel M^1 on shaft M. The pinion P does not rest in a stationary bearing, but revolves upon a stud-pin, which is bolted to the slotted or open bracket P^1. The opening in this bracket is concentric with M^1, so that the pitch-line of the pinion P meets the pitch-line of M^1, in whatever point of the slot P^1 the stud-pin may be secured.

The same wheel M^1 and pinion P will therefore serve with a number of pinions L^1 of different sizes, by the exchange of which the machine receives a different speed.

It must be remembered in the arrangement of the gearings that the screens and the cutter will work more satisfactorily if not subjected to many changes of speed.

The paper, while passing over the different parts of the machine, is always kept

under a strong tension, which must stretch it somewhat lengthways, especially while it is wet. The first press, in drawing the web from the wire, where it is yet in very soft condition, will stretch it somewhat; another smaller addition to its length is made by the second press, while it may shrink on the dryers, and become elongated again on the calenders.

If all the pulleys have been fixed for a certain speed, weight of paper, and kind of pulp, so as to adapt themselves to these elongations and contractions, and suddenly a change in the pulp occurs, it is beaten longer or shorter, or more linen, straw, or imperfections have entered into its composition, it will be found that the first press and following parts are pulling the web either too much or too little for its changed character and tenacity, and the paper breaks or is injured. The same experience will be had, if the paper be suddenly made thicker or thinner. Even if the speed of the whole machine only be changed, everything else remaining as before, the paper may be differently formed on the wire; it may leave the couchers with more or with less water, and its tenacity will be decreased or increased.

In any one of these cases, which occur frequently, the relative speeds of the presses, dryers, and calenders may have to be slightly changed.

A number of strips of canvas or lagging, as wide as the face of the pulleys, is usually kept on hand for this purpose.

They are, when needed, covered on one side with melted resin, and laid on the surface of the driving or driven pulley to increase its diameter. Through the number and length of the strips, held on the pulley by the resin, any slight change of speed can be produced, and, though a very rude expedient, this lagging is used even at the present time.

We have seen cone-pulleys and expanding-pulleys of many different constructions used for this purpose; but the former take too much room and are expensive, and most of the latter may be found covered with lagging, after running a short time, which is evidence that they are considered worthless by the best judges, the machine-tenders.

Some of these contrivances are too complicated; many get out of order easily, and others cannot be adjusted without stopping the machine.

The only expanding-pulley or changeable speed-pulley, which we have seen extensively and successfully used, is that invented and patented by Thomas H. Savery, a member of the firm of Pusey, Jones & Co., of Wilmington, Del.

The employment of toothed or friction-wheels for the transmission of power from the hand-wheels to the scroll or screws, which expand or contract the segments forming the pulley, is considered a new and important feature. It has made the expanding-pulley a success, as it enables the operator to adjust the speed of the roll which it is driving, with accuracy and ease, while the machine is running and the pulley revolving.

This pulley is represented—

In Fig. 89, showing its section on the line B^1 B^1 of Fig. 90.
In Fig. 90, showing its section on the line B B of Fig. 89, and
In Fig. 91 by a perspective view.

The pulley-rim is composed of six segments A, each having its arm A^1, which fits snugly, but slides freely endwise in a pocket planed in the body L, which forms

Fig. 89.

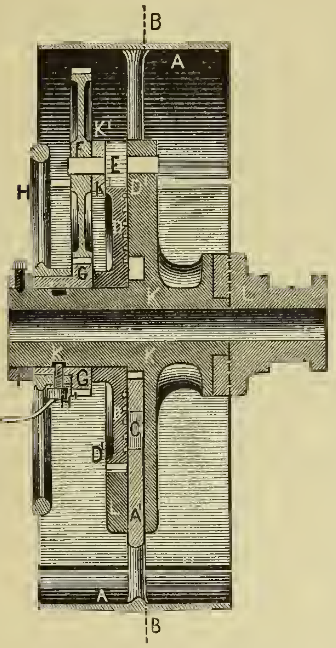
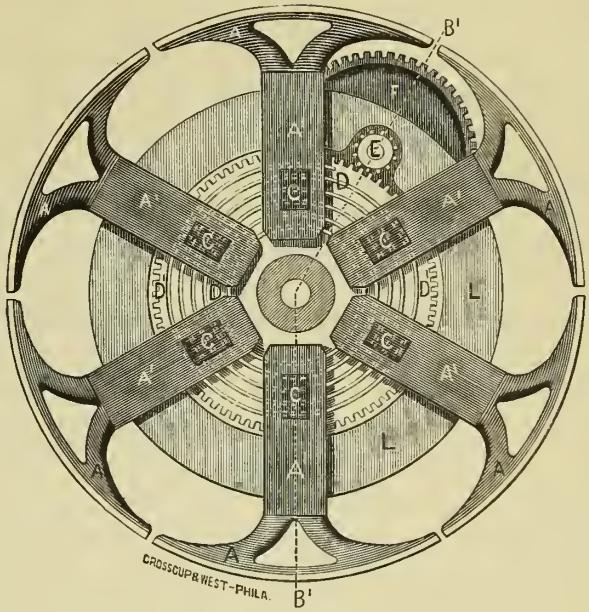
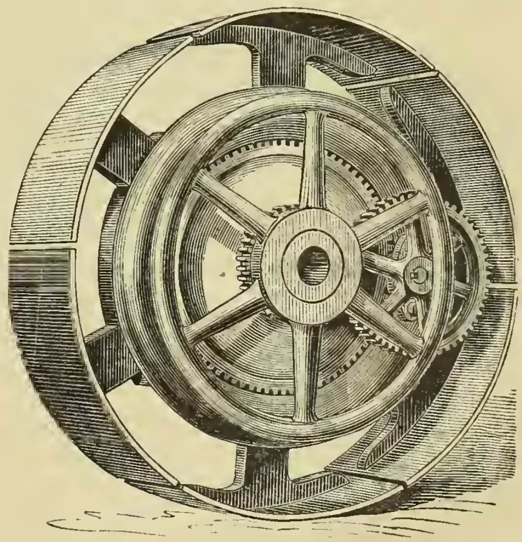


Fig. 90.



part of the hub K. Into oblong openings in the arms A^1 brass blocks C are fitted, which have projecting teeth fitting into and engaging with the scroll or square spiral thread D on the side of the spur-wheel D^1. It is evident that, when the scroll is revolved in one direction, all the arms must approach the centre, and the diameter of the pulley will be decreased; but, when revolved in the opposite direction, the diameter will be increased by the arms being thrown outward.

Fig. 91.



The hand-wheel H, secured to the spur-wheel G, moves the scroll D by means of the intermediate wheel F and pinion E, both of which are keyed on one shaft, separated by the collar K^1. The hand-wheel H has a movement in common with the other parts of the pulley, and, being in a prominent and accessible position, the operator's hand can at any time be applied to it to accelerate or retard its motion. As the hand-wheel must move freely upon the hub G of the pulley, it has, in some in-

stances, a tendency to change its relative position by turning on it without outside assistance, and consequently changes the speed of the roll. To prevent this occurrence the pulley may be safely locked in any position, so that when the desired speed is once gained, it can only be altered by the hand of the operator, by means of a simple and efficient arrangement.

The steel set-screw H^1, which passes through the hub G, its point resting in the groove prepared for it on the hub K, is provided with a small handle, extending outward between two arms of the hand-wheel, and the slightest tap in one direction upon this handle will at once tighten the whole mechanism, so that it would be difficult to move it, while a tap in the other direction, turning the handle only a short distance, will loosen the wheel, so that it will move again quite freely.

The small wrought-iron collar I is fastened on the hub K by a set-screw, and prevents the hand-wheel and pinion from moving from their proper positions.

Some of these pulleys are keyed on to the driving-shaft; others are made with a clutch-hub, fitting loosely and revolving freely upon the shaft; their movements are imparted to the shaft through the sliding-clutch L, when engaged with the hub K, as shown in Fig. 89; but when the clutch is thrown out of gear by the shifter, the pulley continues to revolve and the clutch stops.

In these pulleys the expansion is so gradual that the hand-wheel must make eighteen revolutions to turn the spiral screw D once. One turn of D increases or decreases the diameter of the pulley one inch. A 36-inch expanding-pulley represents all possible diameters between 34 and 38 inches, admitting a variation of four inches in all.

The application of lagging is distasteful to machine-tenders; it does not admit of such slight variations of speed as the expanding-pulley, and sometimes drops from the pulleys while running.

The expanding-pulley, described above, has become a favorite with the machine-tenders because of its convenience and neatness, and, as it removes some of the irregularities which cause the paper to break, it is a source of economy.

The shafts of the first and second press, of the dryers and calenders of the machine shown on the plate, are furnished with these expanding-pulleys P, their couplings being thrown in or out from the front side of the machine by means of the arrangement shown on previous plates.

Every machine should be provided with convenient means, by which any part of it can be easily and quickly thrown in and out of gear.

165. Size and Speed.—It is natural that a manufacturer should endeavor to make as much paper with his machine as possible, because very little more capital and labor are required for the production of 100 feet than of 50 feet per minute, if he has power and machinery enough to do it.

The faster the machine runs, the less time is allowed for the formation of the paper and for the escape of the water on the wire, presses, and dryers, and if the speed is increased too much the quality must suffer.

If every part is construeted with the utmost care, substantially and true, a machine like the one represented on Plate IV, with a wire 33 feet in length, and seven drying-cylinders of three feet diameter, can make news-print paper at a speed of from 110 to 130 feet per minute.

If the length of the wire and the number of presses and drying-cylinders are increased, the maehine may be made to run faster, and there is no doubt that improved machinery will, in the future, admit of mueh higher speeds than those at present used.

The paper-mills depend in this matter almost entirely upon the perfeetion of the tools and the skill of the operatives and engineers in the machine shops.

The width of the machines has also been increased, until wires 86 inches wide are now quite numerous, and some of 90 and even 100 inches are in use.

A positive limit is set to the width of a maehine of the present construction by the proportions and capabilities of the human body. The machinc-tender must be able to reaeh the middle of the sheet with onc hand, so that every part of it ean be taken hold of by the men on both sides.

Wider machines than those mentioned would certainly offer difficulties in this respect.

It is also a fact that wires and felts will not last so long on wide machines as on narrow ones, and maehine-tenders, who are competent to run them, receive higher wages.

A larger machine, on the other hand, allows of a larger variety of sizes of paper to be made; it takes less room, and costs less than two machines of half its width. The same quantity of paper, which loses only two trimmings or cdges on a wide machine, would give twice as mueh waste from this source if made on two narrow maehines.

Taking everything into consideration, it is our opinion that paper ean be madc as cheaply on 62 to 72-inch machines as on wider oncs, though the latter may be preferred for other reasons.

166. Foundation.—The foundation on which the paper-machine is mounted, must be solid and united, so that not the slightest vibration or ehangc of position of any of its parts can take plaee.

Wooden sills, about 10 to 12 inches squarc, underlic the frames of the maehine and the stands whieh earry the shafts. Timbers whieh will withstand the influence of water for a long time, sueh as white oak or hard yellow pine, should be selected for them, and they must be conneeted crosswise by numcrous joists and short sills, mortised and pinned together, so as to form a strong framework.

This framework may rest on stone walls, about 2 feet wide, extending as far as the sills, if the paper-machine stands on the lower floor; but, if it is situated on the engine-room floor, the walls must be higher and eonsequently stronger, or they may be entirely dispensed with, and replaeed by iron girders and eolumns. The spaee below the machine is then occupied by a portion of the gearings, pumps, stuff-catcher, stuff-chests, &c.

The wooden sills, on which the frames and stands are fastened with bolts and wood-screws, must present a perfectly level surface, but the floor between them, under the machine, should be a little lower, and incline towards openings, through which the wash-water and impurities are carried off. The floor around the machine should also be provided with such openings, and pitched towards them, as it would be otherwise difficult to keep it clean and dry.

Heavy machinery is frequently moved over these floors; they must therefore be strong. The machine-room floor at Messrs. Jessup & Moore's Rockland Mill is composed of narrow 4 inch planks laid on iron joists and girders, and deserves imitation.

167. Machine-Room.—Many paper-machines are found in buildings, which they fill up to such an extent that there is not room enough left on the front side to take out a roll in a straight line, nor to reach any part of the gearings without climbing over some shafts. This is not only inconvenient and dangerous, but causes loss of time, and is therefore the reverse of economy.

The machine-room, with only one machine standing in the middle, should not be less than three times as wide as the wire with 6 feet added; or the room for a 72-inch machine should be at least 24 feet wide.

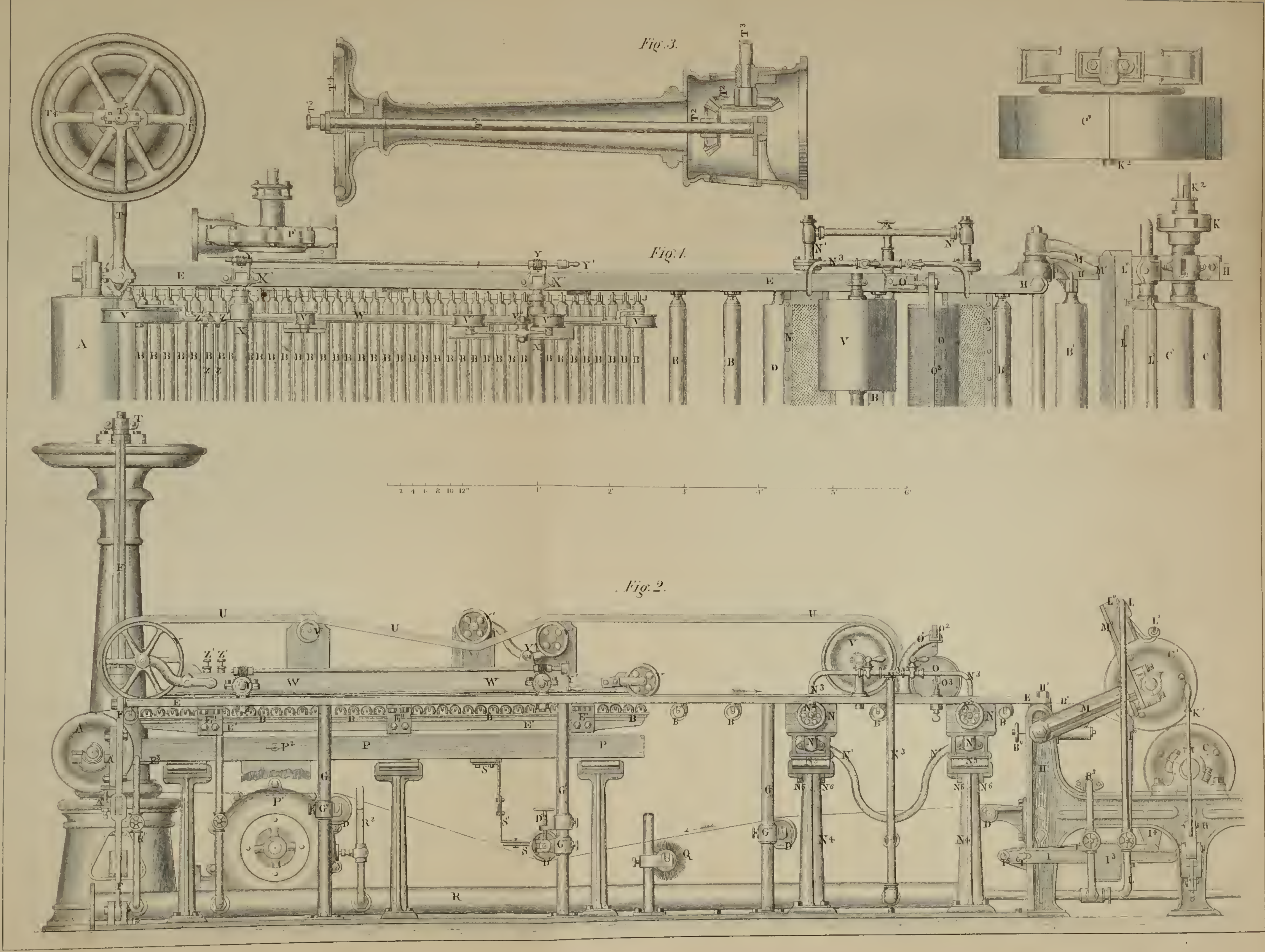
If two or more machines, with their front sides facing each other, are located in one room, the space between them need only be a few feet wider than the widest of the machines, and will serve for both.

168. Ventilators.—If the steam which is evaporated on the dryers, is allowed to strike the cold ceiling, it condenses again, and every drop of water which falls upon the paper creates a wet and weak spot, causing it to break, or leaving a mark on it. In cold weather these drops may become so numerous that it is nearly impossible to make paper.

Formerly a sort of chimney, constructed of boards, and called *the hat*, was used to carry off the steam from the dryers, and can yet be seen in many mills. Its lower edges extend in all directions beyond the space occupied by the drying-cylinders, and its sides converge, like those of a pyramid, to the ceiling, from whence they ascend in straight lines until they reach the open air, protected by a roof against the rain. The steam escapes through it; but in cold or damp weather some of it condenses on the insides of the chimney, which may have been cooled by the free communication with the air from above; and numerous contrivances, such as spouts along the corners and edges, and felts spread across the open space, are resorted to for the interception of the drops.

In modern mills no additional floor is allowed above the machine-room; the roof, which covers it directly, being lined inside with flooring-boards. The surface of the ceiling thus formed is made perfectly smooth with several coats of paint and varnish, which prevent the drops from gathering on it. All the joints must run up and down; and if several lengths of boards are required on a side, care must be taken that the ends should not meet on any part of the ceiling above the machine, as the drops may stop at these cross-joints on their downward flow and gradually fall off.

Plat. I.



Plat. II.

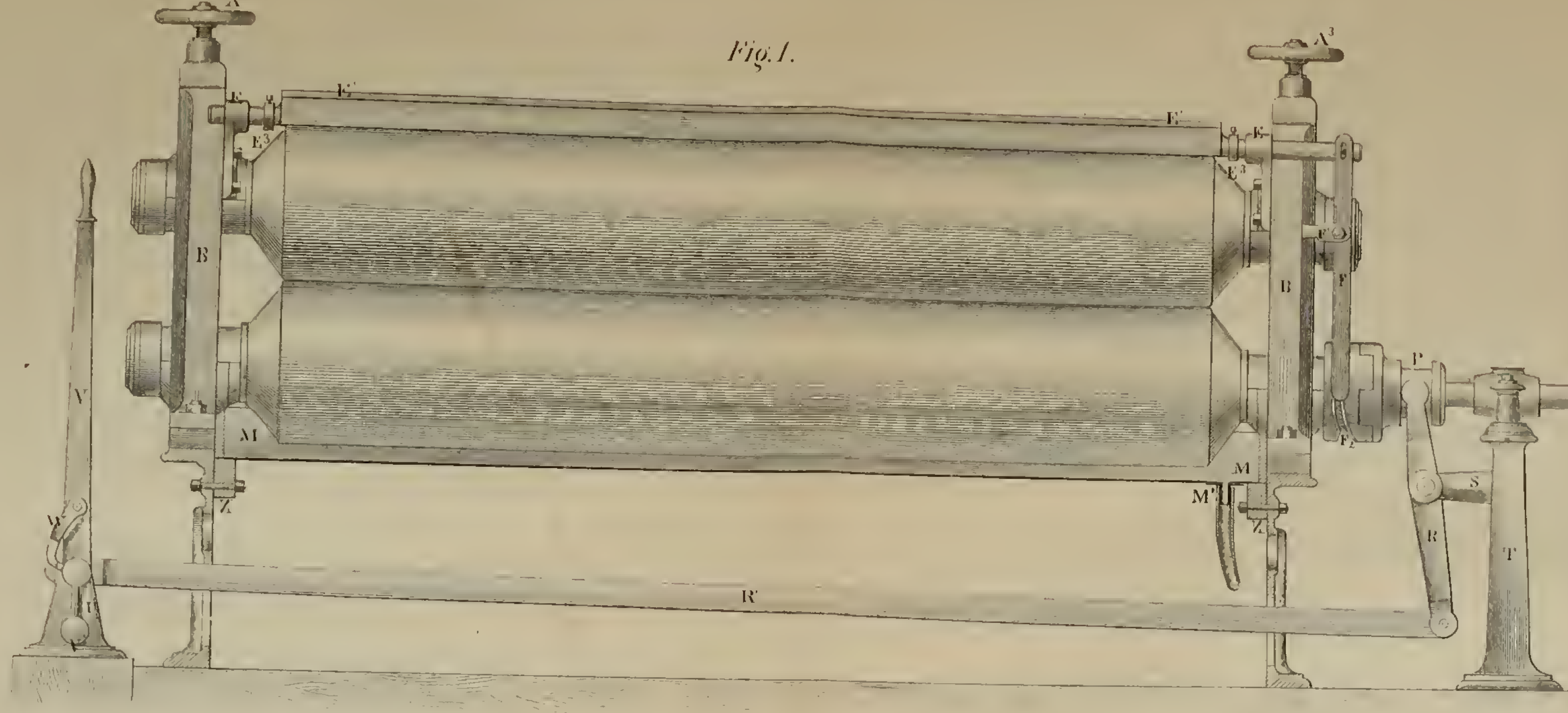


Fig. 1.

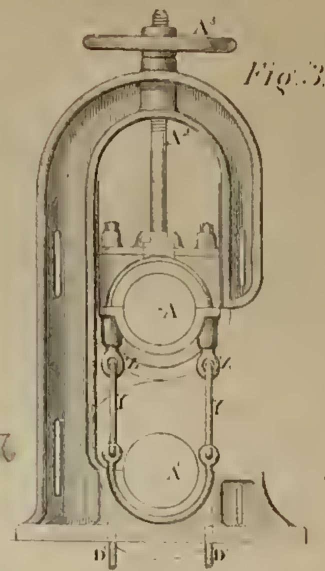


Fig. 3.

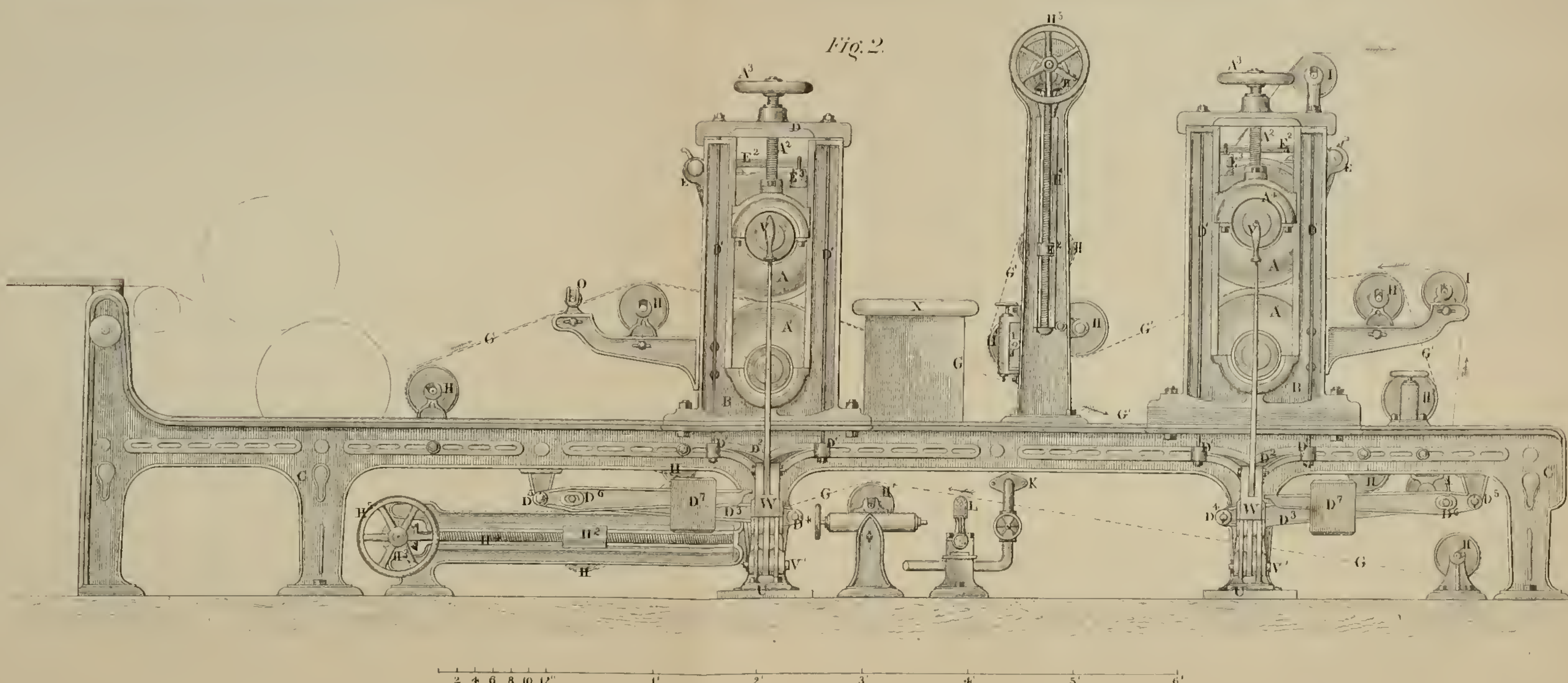


Fig. 2.

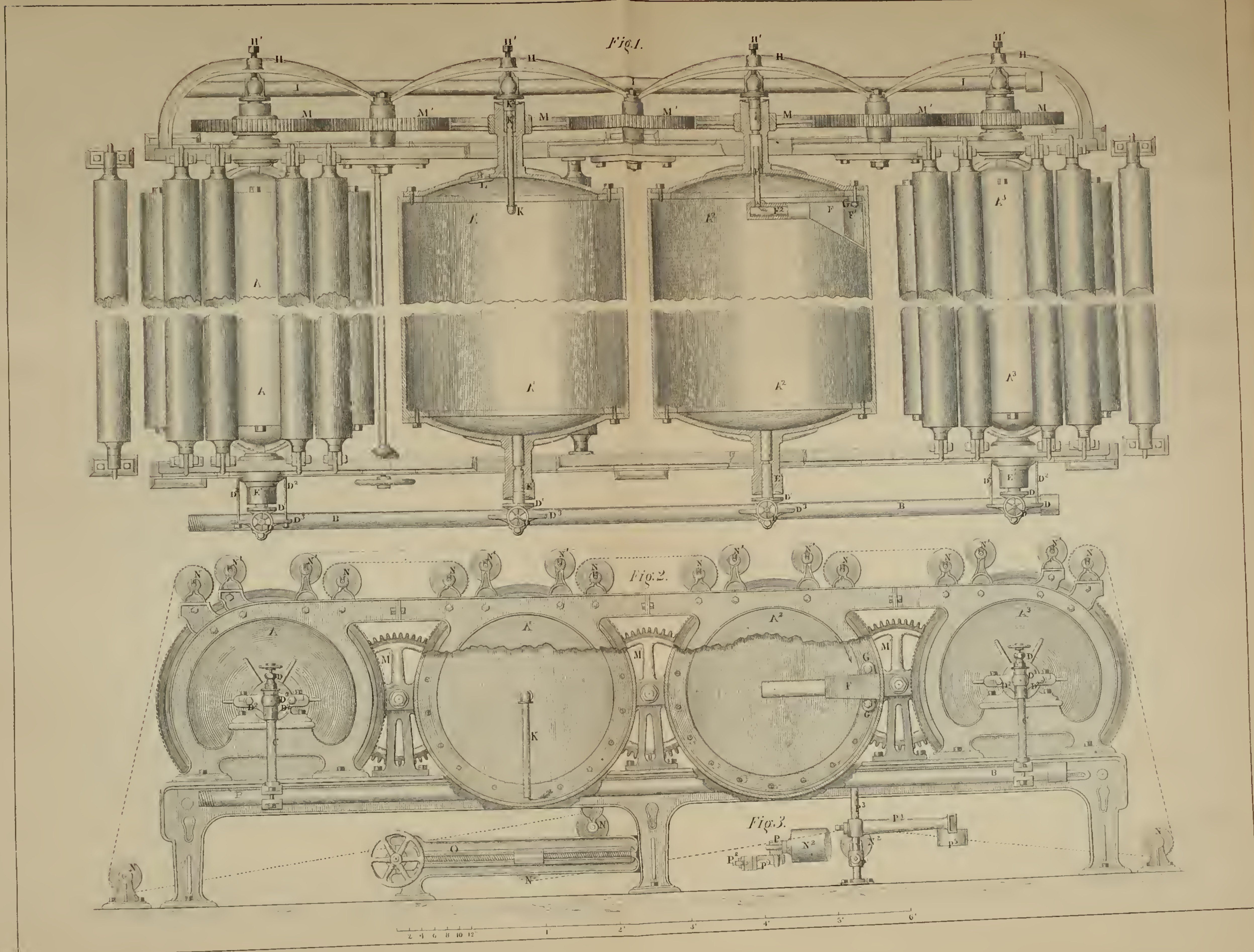


Fig. 1.

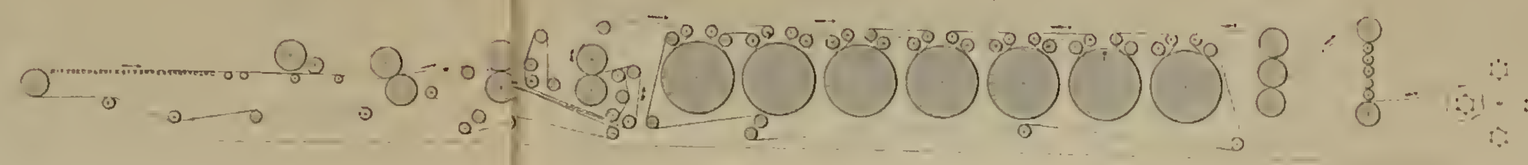


Fig. 2.

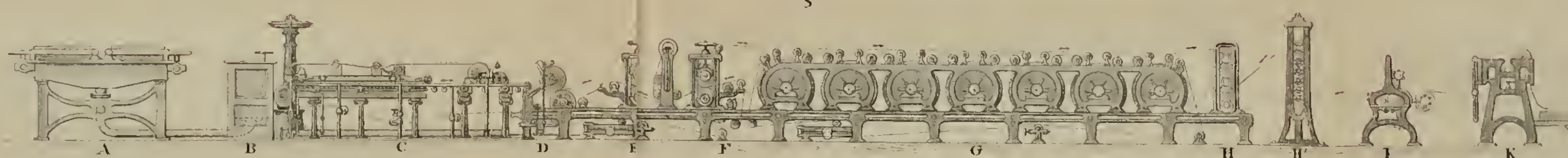
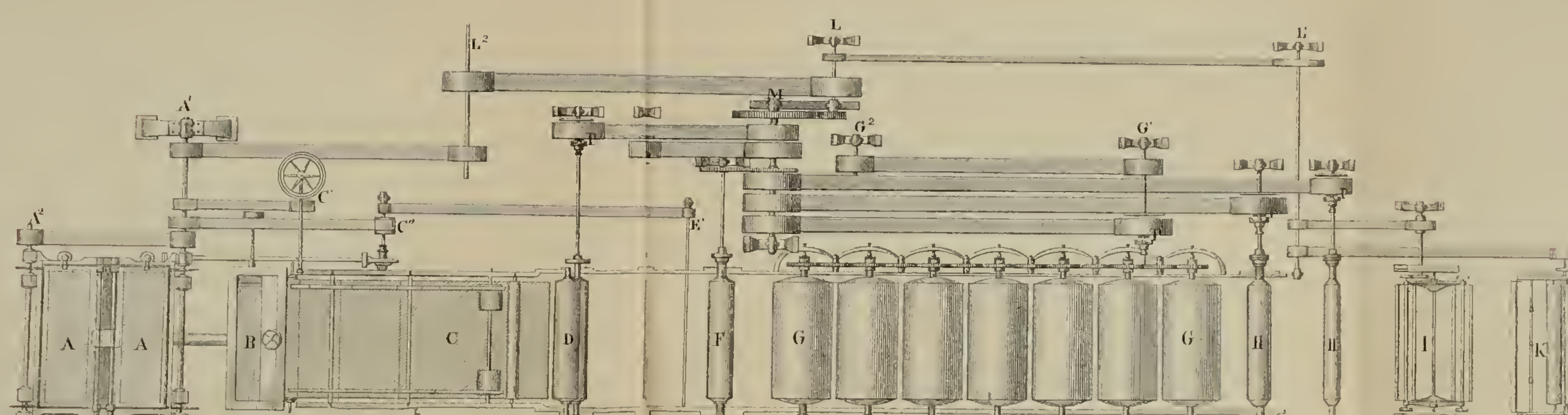


Fig. 3.



6" 12" 1' 2' 3' 4' 5' 6' 7' 8' 9' 10' 20' 30 40' 50'

If the ceiling is very steep and smooth, the water runs off to both sides on it, and gives no trouble.

The cumbrous and darkening *hat* is at present replaced by a set of windows, called a *ventilator.* An oblong opening, about 4 to 6 or more feet wide and from 10 to 20 feet long, is cut into the highest part of the roof above the dryers, and covered with a second roof, about 4 to 6 feet higher up. A framework around the sides of the opening supports this upper roof, and is fitted for the reception of a number of glass windows on the two long sides, while the two short ends are boarded up. The windows swing on hinges or pivots, so that they can be more or less opened or shut by the pulling of a chain or rope from the floor below.

Whenever the wind blows strongly, the windows on the side from which it comes should be shut against it, and the steam allowed to escape through those on the other side.

To prevent, in cold weather, the condensation of steam on the ceiling, a series of wrought-iron steam heating-pipes may be suspended near it above the machine.

If live steam is used for this purpose, it may be conducted through several lengths of 1 to 2 inch pipes, above and parallel with the machine, then through large cast-iron heating-pipes on the floor, to escape finally in condensed form into a receiver, which contains the feed-water for the boilers.

If the escaped steam of an engine is available, the pipes must be larger, to avoid contraction and the back pressure which inevitably results from narrow ones.

These pipes heat the ceiling and keep the steam in vapor form until it escapes through the ventilator.

(B) CYLINDER PAPER-MACHINE.

169. General Construction.—This machine derives its name from the wire-cloth-covered cylinder, which performs the same duties as the wire of the Fourdrinier machine.

All the parts which compose a cylinder-machine, except the making or forming-cylinder and the first press, are constructed like the corresponding parts of a Fourdrinier machine.

The wet-machine (see Chapter IV, Section IV), represented by a front elevation and plan in Fig. 92 and Fig. 93, shows the screen, making-cylinder, and wet-felt, and will facilitate the explanation of the working of a cylinder-machine.

The shaft of the making-cylinder H rests at both ends in the sides of the wooden vat I, and the openings made by its bearings are covered by the projecting incasements H^1 and H^2.

The vat I is filled with diluted pulp, and the fibres deposit themselves on the wire-cloth, which covers the cylinder H, while the water passes through it and is taken off by the fan-pump K. This pump is constructed like those used with Fourdrinier machines, and bolted directly to the projecting box H^2 of the vat.

The end of the cylinder H, on the front side near H^1, is closed, but the end on the driving-side near H^2 is quite open; it has near the edge a concentric projecting ring (D in Fig. 94), which fits into a like aperture in the side of the vat. The connection of the fan-pump K with the box H^2 must be low enough to enable the water in the cylinder H to flow away through it.

The pulp enters into the partition I^1 over the lip E of the screen-vat, and flows from there in the direction of the arrow to the cylinder H.

The fan-pump K throws the waste-water into a spout K^1, and through a side channel K^2 into the trough I^2, while the surplus liquid returns to the screen, after having been mixed with fresh pulp in the box A^1. The quantity of this water which is to be admitted into I^2 can be regulated by a gate between K^2 and I^2.

If more fresh pulp and waste-water are delivered in the vat I than the making-cylinder can take up, they must flow over the latter unless another outlet is provided. As much of the waste-water in the trough I^2, as may be superfluous, is therefore allowed to return to the stuff-chest through a spout H^3, and over an upright sliding-gate, which separates H^3 from I^2, and by its higher or lower position regulates the height of the pulp in the vat.

The bottom of I^2 is perforated by numerous holes, for the purpose of mixing the waste-water uniformly with the pulp; but if these openings permit the passage of too much water, some of them must be closed with wooden plugs.

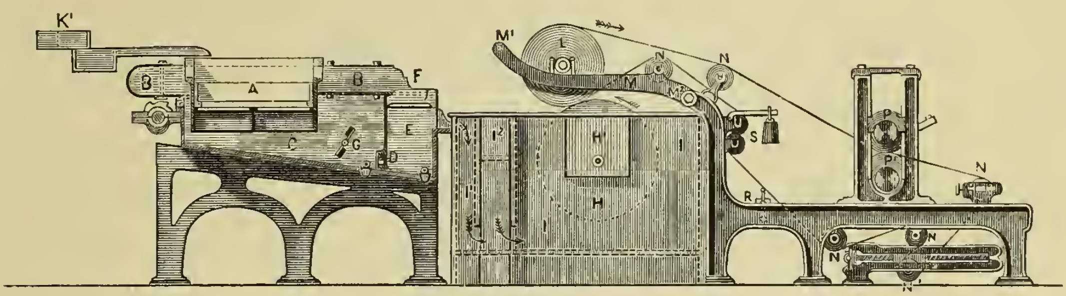
A second trough, similar to I^2, and with the same connections, is sometimes put into the forward end of the vat, for the purpose of additional dilution.

The bottom of the vat should be, as much as possible, of the same shape as the making-cylinder, to prevent any deposits from the pulp.

The cylinder H exercises not only the functions of the wire, but also those of the lower couch-roll. The upper couch-roll L rests freely on it, its journals being supported by the cast-iron arms M, which swing loosely on the studs M^2, fastened in elongations of the press frames.

This couch-roll L is constructed of wood bolted on iron heads, and of about 12

Fig. 92.



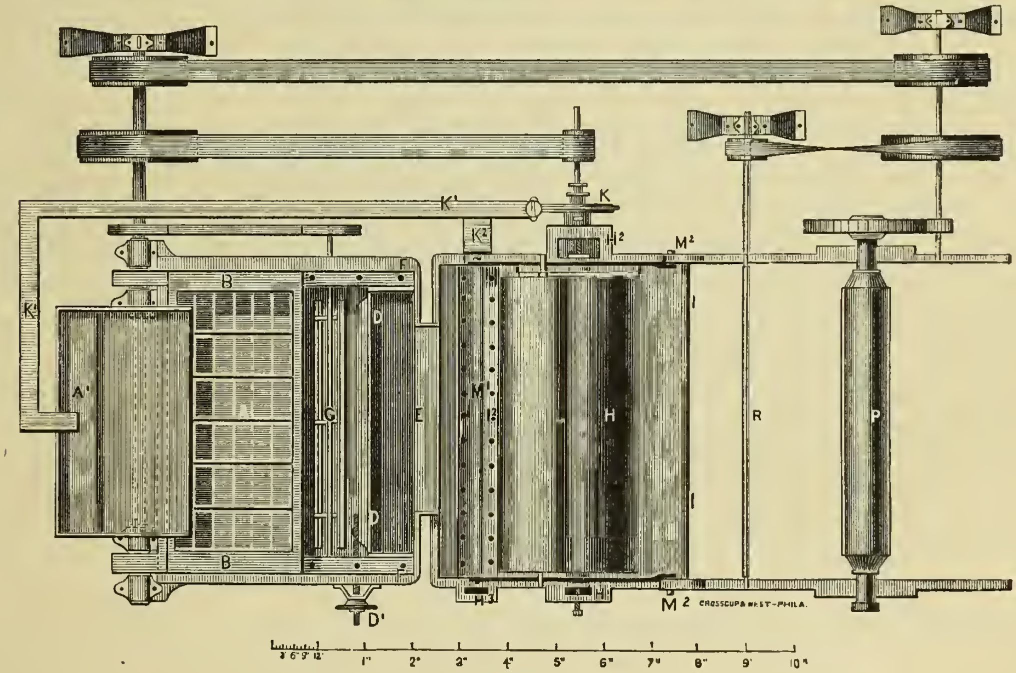


Fig. 93.

to 18 inches diameter; but several layers of felt must be wrapped around it to give it the necessary elasticity. We have also seen the surface covered with sponge tacked on the wood, and felt put over it, but it is very difficult to make it uniform in this way.

The wet-felt passes around the coucher L, is carried by the rolls N N and stretch-roll N^1, and supports the paper on its way through the press-rolls P and P^1. From

the wet-machine, represented in our cuts, the paper is removed in a wet state, after it has passed the first press; but in a regular cylinder paper-machine the wet-felt is longer than in our drawing, and extends under the second press in the same way as [see Plate II] on the presses of a Fourdrinier machine.

The wet-felt is met on its return trip, after it has delivered the paper to the second press, by the fast-running felt-washer R. It has been soaked with water from a shower-pipe just before reaching it, and is thus constantly washed. The surplus water which it may contain is forced from it by the succeeding press-rolls S.

The use of a revolving-brush on the part of the cylinder which is not covered by paper, is of great advantage. The stiff bristles projecting from a wooden cylinder are forced into the meshes of the wire-cloth by the weight of the brush, and thus keep it free and clean while revolving with it.

If the paper is not wide enough to occupy the whole width of the cylinder, that part of the surface which is not required is simply covered with thin but strong linen cloth.

170. Formation of the Paper.—The paper is formed on this machine in the following manner:

The pulp, diluted by the waste water admitted through trough I^2, is spread across the whole width of the vat, and fills it to the height of the overflow-gate, which guards the entrance to the spout H^3. The rim of one of the heads fits into the side of the vat and runs in it, while the other end of the cylinder is closed by a solid plate; the pulp can therefore have no communication with its interior except through the meshes of the wire-cloth. The water pours in through them, and is removed by the fan-pump K, which connects with the inside, while the fibres adhere to the wire and form a web. The pressure which forces the water through, is equal to the difference in height of the pulp outside and of the water inside of the cylinder. The upper couch-roll L presses water out of the paper by its own and by additional weight, which may be fastened to the rod M^1. By means of the same rod M^1, it is easy at any time to raise the upper couch-roll from the cylinder.

As soon as the paper comes in contact with the wet-felt, under the upper couch-roll, it leaves the wire-cloth, follows the felt on its passage through the first press, and is then conducted through the second press and to the dryers, as in the Fourdrinier machine.

171. Construction of the Making-Cylinder.—The most important part of this machine—the making-cylinder—is represented in Fig. 94 by a section, and partial views of the heads or ends and of the spiders are shown in Figs. 95, 96, and 97.

A (Fig. 95) is the full head which closes the front-side end of the cylinder; it is made of brass, and consists of a hub, arms, and rim, and of a copper plate, which is fastened to the rim with screws.

Numerous brass cast spiders B B (Fig. 97) are necessary to support the surface, so that it cannot yield in any part to the pressure on it.

C (Fig. 96) is the open end of the cylinder, the rim D of which fits into an opening of the same size in the side of the vat.

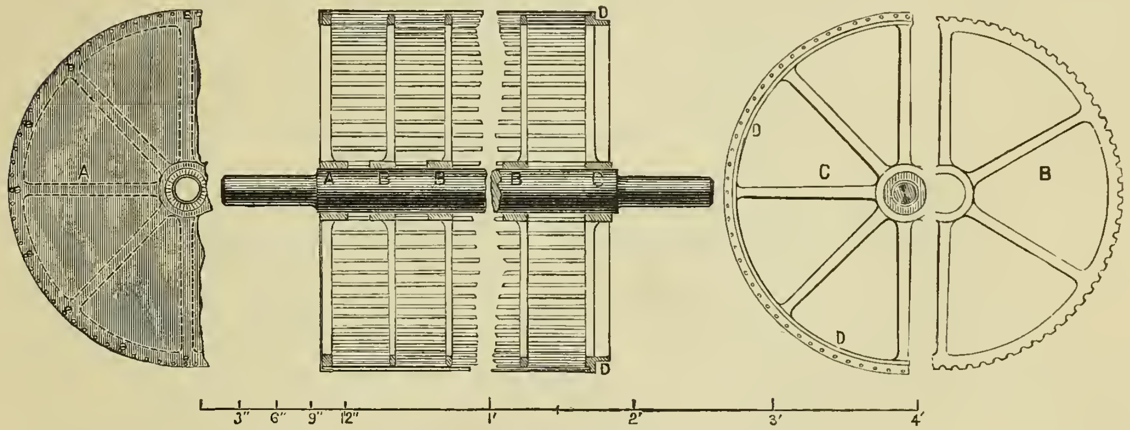
The skeleton frame, which supports the wire-cloth, is formed of a large number of brass rods of No. 3 ($\frac{1}{4}$ inch) wire, lying, as shown in section, Fig. 94, parallel with the shaft.

The diameter of the spiders B B is $\frac{3}{8}$ inch less than that of the heads A and C, and a half circle (Fig. 97) is cut out on them for every brass rod, serving it as a bearing. Full circles or cylindric holes in the heads correspond with these half-circle bearings on the spiders, and the rims of A and C are large enough to leave a distance of $\frac{1}{32}$ inch between their outside circles and the outside edges of these holes. The rims of A and C are $\frac{9}{16}$ inch thick, and the holes in one of them are bored clear through, while they enter in the other only $\frac{3}{16}$ inch deep.

All these holes must be exactly in line; the rods are introduced through one of the heads passed through the half circles on the spiders, and find a resting-place in the short holes of the other head.

Around these rods is wound No. 16 ($\frac{1}{16}$ inch) copper wire, three turns for every

FIG. 95. FIG. 94. FIG. 96. FIG. 97.



inch of the width of the cylinder (not shown in the section). A half circle of $\frac{1}{16}$ inch diameter must be turned into the brass rods as a seat for this wire. The whole cylinder skeleton is for this purpose put in a lathe, where the half circles are cut out in such a manner that the copper wire fits into a bearing on every rod.

The wire on which the paper is formed cannot be spread directly on this copper wire; it requires yet another support, usually a No. 14 brass wire-cloth, which is made endless by a seam, and slipped on the cylinder frame. The finer making wire-cloth may be of any number between 50 and 70, or more, according to the quality of paper, and is simply slipped over the coarse one.

172. Merits and Demerits of the Cylinder-Machine.—The manner of construction of the cylinder, and its connection with the upper couch-roll and wet-felt, exclude the possibility of its being shaken sideways. The fibres will therefore deposit themselves on the wire-cloth only in the direction in which the paper moves, that is, lengthways. Paper made on a cylinder is in this respect inferior to that made on a

Fourdrinier wire, which being shaken sideways, causes the fibres to intertwine themselves in all directions. Cylinder paper has all its strength in the direction in which it has travelled over the machine, will split easily lengthways like wood, and with more difficulty across the grain or fibres.

The direction in which cylinder paper has been made, can always be easily found; it is the one in which it splits or tears most readily.

Since it is impracticable to shake the cylinder, several improvements have been patented by which the fibres can be shaken laterally before they deposit themselves on it.

They consist principally of agitators, with screw-shaped wings, which revolve rapidly in the vat close to the cylinder.

Though they cannot make the paper felt itself as well as on a Fourdrinier wire, these agitators are yet useful and frequently applied.

It is evident from the construction of the cylinder-machine, that it is much cheaper, and that its management requires less skill than that of a Fourdrinier machine. The latter also uses up deckels, jackets, more and longer wires, and more power.

The cylinder machine furnishes an inferior paper, but it can be operated at so much less expense that it should be used for all those grades in which the superiority of Fourdrinier paper is not recognized by a comparatively higher price.

Nearly all our coarse wrapping and even a great deal of news-print and book paper is made on cylinder machines.

173. Combination of Several Cylinders.—The diameter and consequently the wire surface of a making-cylinder is very limited, and the pressure of the pulp in the vat is the only means by which the water can be forced from it.

Very heavy sheets cannot, therefore, be made on this machine, but if the paper from two or more cylinders is united on one wet felt, it will, after having passed the presses and dryers together, form a solid web.

Two making-cylinders are for this purpose placed in one vat, and the wet felt must be long enough to envelop both couch-rolls.

The paper from the second cylinder follows the felt until it meets the paper on the first one, and from there the double web travels as one to the presses.

A pipe or spout connects the cylinders with one fan-pump, which serves for both.

These double cylinders are largely used for card, collar, heavy Manilla, such as bag-paper, and many other kinds.

Paper, the two sides of which are of different colors or qualities, can be made by giving a separate vat to each cylinder, and supplying them with different pulp.

Three and more, up to six, cylinders have been combined in one machine for the manufacture of heavy boards. The number of drying-cylinders must be increased in the same proportion, and as many as 16 to 20 dryers, of 3 feet diameter, may be seen in some of these machines.

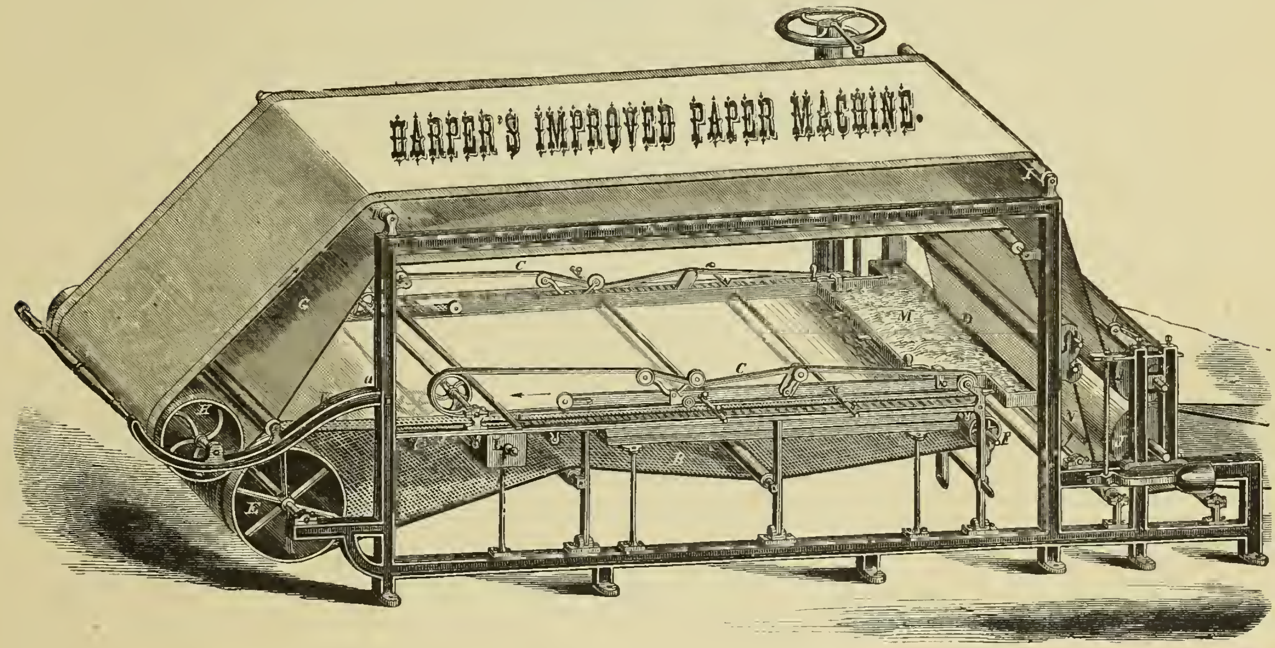
Combinations of more than two or three cylinders have, however, not been successful, and have in some mills been replaced by Fourdrinier wires.

(C) HARPER'S IMPROVED PAPER-MACHINE.

174. Construction.—Mr. James Harper, paper manufacturer, near New Haven, Conn., has patented and constructed a combination of the Fourdrinier wire and of the cylinder-machine, represented in Fig. 98.

The wire-cloth B is, as usual, supplied with a breast-roll F, deckels C, suction-box L, and apron M; but the lower coucher E is an open forming-cylinder, on which the Fourdrinier wire B is substituted for the fixed wire-cloth. The upper coucher H rests on levers K, which turn round the points *a* of the frame A. The wet-felt G

Fig. 98.



passes around the upper coucher H over the felt-rolls I to the first press, and carries the paper to the forward end of the second press. Returning, it is washed, like the wet-felt of a cylinder-machine, by the felt-washer N, and pressed out between a pair of small rolls immediately afterwards.

The sand-tables and screens are separate from the machine, and may be located below the floor, and the pulp delivered on the apron M and within the sides D by a fan-pump.

175. Advantages over other Machines.—The advantages claimed for this machine are:

That the paper passes from the wire to the wet-felt without assistance, and that the losses of pulp, which on Fourdrinier machines occur in this place, are avoided;

That thick paper cannot be crushed by the couchers; and that the thinnest paper, which cannot be taken from the coucher of a Fourdrinier wire to the wet-felt, can be made on this machine;

That no water is required for shower-pipes, as none are used;

That the felt is constantly washed and kept clean;

And that there is a great saving in wires and felts.

The length of the wet-felt is reduced as much as possible by the use of a short wire; and the inventor claims that this short wire is as effective as a longer one, if supported by the same number of tube-rolls.

Notwithstanding the use of a short-wire, the wet-felt is yet very long and costly.

Seven of these machines have been built, besides the one which is in operation at Messrs. Harper & Brother's mill; but several have, as we were informed, been abandoned again, because the expense caused by the frequent renewal of wet-felts was too large.

Experience is required for the management of any new machine, and many difficulties which are at first encountered will be overcome in time by skill and perseverance. The advantages, which this machine seems to offer over the cylinder or Fourdrinier machine, should at least secure for it a fair trial on the part of manufacturers.

SECTION VI.

Sizing in the Web, or Surface-Sizing.

176. Preparation of the Size.—Nearly all the paper which is used in England and in the United States for writing purposes, especially for letters, is coated with animal size or glue, in the same manner as hand-made paper.

The size is prepared substantially as it was many years ago, but it is at present applied to the paper on the machine, and the labor of handling the sheets has, by ingenious mechanisms, been reduced so much that it cannot be considered a serious objection, if compared with the advantages which this system of sizing has over all others.

Most manufacturers make their own size, in a room adjoining the machine, or below the machine-room, if the latter is situated on the second floor.

The gelatine or glue which forms the basis of this size is found in the muscular fibres, skins, ligaments, cartilages, tendons, and membranes of animals, and it constitutes about half the weight of the bones.

It is heavier than water, without taste, smell, color, and neither acid nor alkaline. It is very soluble in boiling, but only sparingly so in cold water. When two parts and a half are dissolved in a hundred parts of water, the liquid congeals on cooling. The jelly sours in a few days, especially in summer; it then liquefies, and before long exhibits all the phenomena of putrid fermentation. Clippings of hides, parchment, gloves, and scrolls, or parts of the hoofs and ears of oxen, horses, sheep, and calves, are the raw material from which it is extracted by paper-makers.

Nothing but the best of hide-clippings are used for No. 1 letter-paper, but cheaper qualities may be used for the lower grades. They are first softened by soaking during several days in large wooden tubs filled with water, and then put into a wooden cylinder of from 4 to 6 feet diameter and about 10 feet length, which revolves on a horizontal shaft. Its surface is composed of boards perforated with numerous holes, one of which is fastened with hinges and serves as a door for filling and emptying. This washing-machine is immersed in a trough up to the centre, and receives a revolving motion from a pulley outside; a stream of fresh water enters constantly through holes in the hollow shaft, while the dirty water escapes through those in the surface.

The clippings, thus cleaned, are put into a tub of about 6 to 8 feet diameter, made of wood, or rather of galvanized iron, which should be provided with a false, perforated bottom. Steam is introduced below this false bottom, through a coil-pipe with numerous holes, and thus prevented from coming in direct contact with the

clippings. The water is never allowed to boil, but to reach only from 180 to 190 degrees Fahrenheit, and kept at that temperature for some time (12 to 18 hours). The solution of gelatine thus obtained is drawn off into wooden tubs, which serve as receivers, and must be situated beneath the one in which the extracts are made.

As the liquid may contain pieces of hide or scrolls and impurities, it is advisable to strain it while leaving the tub in which it was prepared.

A box, about 8 to 12 inches square, is usually fastened in the latter for this purpose; it stands either upright, attached to the side, or better, lays flat on the solid bottom, protruding above the false one. This box is perforated all over and filled with clean rye-straw, through which the liquid filters into a pipe, which conducts it to the receiving-tubs; but, before emptying into them, it is filtered a second time through a flannel bag tied to the outlet of the pipe.

An experienced paper-maker and close observer has found that the solution takes up some of the color of the rye-straw while filtering through it, and he substitutes gingham-cloth instead.

Two or three and even four extracts are made of one lot of clippings, and it is therefore impossible to prescribe either the quantity of water which should be used with a certain weight of the raw material, or the time for a solution. It matters little how it is done, provided that all the gelatine contained in the clippings is extracted in good condition and well strained.

The various solutions are mixed together in the receiving-tubs, and there receive an addition of enough alum to be recognized by tasting the liquid. The object of the addition of alum is principally to prevent fermentation or decomposition of the gelatine, and as this takes place easier as the temperature is higher, the proportion of alum should be larger in summer than in winter. As the solutions cool off in the receiving-tubs, they solidify, acquire a gelatinous consistency, and are then ready for use.

According to the quality of the material, about 10 to 20 pounds of clippings or scrolls are necessary for the preparation of a sufficient quantity of animal size wherewith to coat the paper made from 100 pounds of rags.

The following proportions are used for the manufacture of a very good No. 2 flat-cap paper in one of the best mills in this country:

Fourteen pounds of No. 2 clippings or scrolls per 100 pounds of rags are soaked in water during three days, then washed as described. Thirty-six hours are consumed in making only two extracts of this material, which are strained and emptied into tubs.

The best clippings contain so much gelatine, and can be so thoroughly dissolved, that hardly five per cent. of solid matter is left after the extracts have been made.

The gelatine in the receivers is dissolved in a tub provided with a steam-pipe, as it may be required on the machine. The water should be only lukewarm, and the quantity used is ordinarily from one-third to one-half of the volume of the gelatine, but it must be regulated to suit the stuff and the weight of the paper: weak fibres

and thin paper requiring a more concentrated solution than strong fibres and heavy paper. A hundred pounds of light paper may have twice as much surface as the same weight of heavy paper, and certainly need more sizing material.

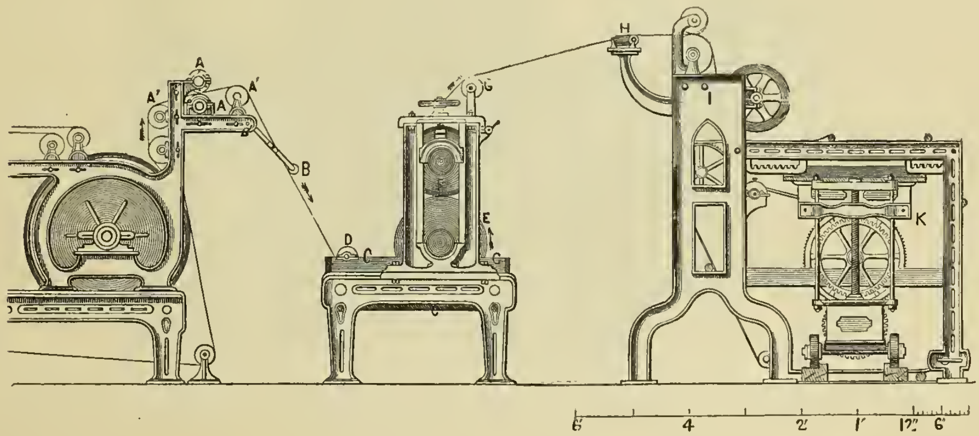
A pump, which stops and starts with the machine, forces this solution into a small receiver on the driving-side of the machine, which in its turn supplies the trough wherein the paper is soaked with it. As it is necessary to keep the solution at the same height in the trough and receiver, an overflow is attached to the latter, through which the surplus returns to the tub from which it was taken.

The preparation of this size, though it seems simple enough, requires experience and judgment; especially must the raw material be carefully selected. No pieces which are in a state of fermentation or partly decomposed should be allowed to be mixed in with it, as they may start putrefaction in the size. If the clippings or scrolls are very large, they must be reduced to convenient sizes.

Ready-made glue in tablets is usually too expensive, as the paper-maker has to pay not only the cost of the material and manufacture, but also of the fuel and labor which were required to reduce the gelatinous liquid to dry glue. By making the extracts himself, not only is money saved, but he also knows exactly what material his size is made of; while even a poor article may be sold to him transformed into dry tablets.

177. Application of the Solution.—The pulp or paper which is to be coated with animal size may have been previously sized in the engines; it is run over Fourdrinier machines, which, preceding the last drying-cylinder, differ in no respect from those

Fig. 99.



described. A front elevation of this last dryer and the succeeding parts of the machine are represented in Fig. 99.

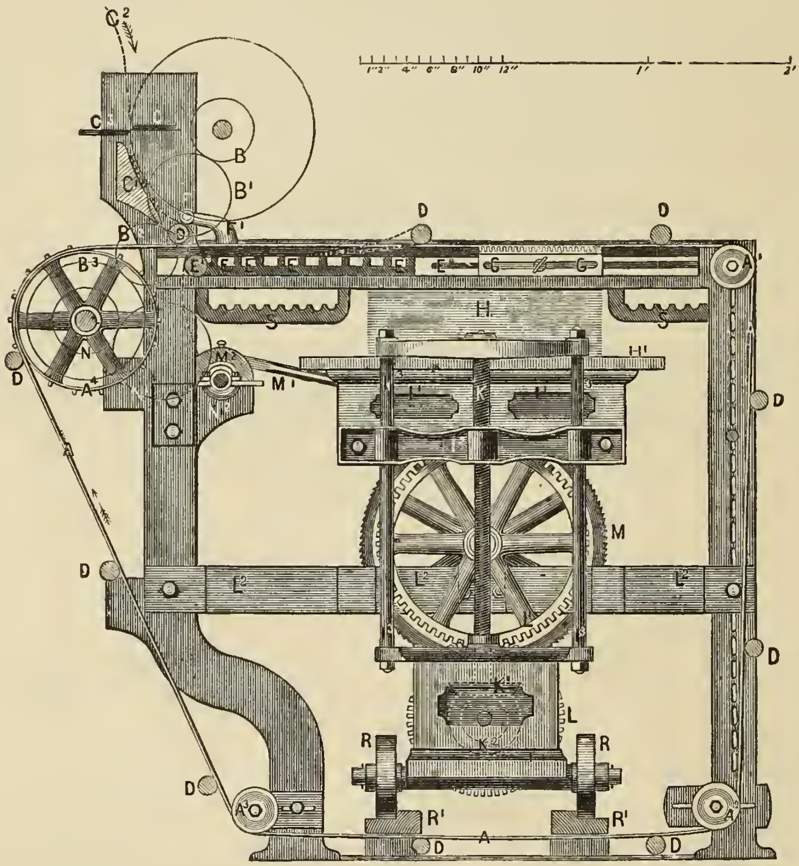
The drawing is taken from a machine built by Messrs. Rice, Barton & Fales, at Worcester, Mass., and in operation at the Holyoke Paper Company's mill, Holyoke, Mass.

The course of the paper is indicated by arrows. After it has left the dryers, it

passes directly through the slitters A A, which are fastened on an extension of the wire-frame. It is carried on the rolls A¹ A¹, and kept in a state of tension by the weight of the roll B, which is fastened to two levers turning around B¹, and simply rests on the paper.

The bearings of the roll D, which the web next reaches, are fastened on the size-tub or trough C. A press, consisting of a brass-covered iron roll F on top of a large wooden roll E, rests on the same frames as C, the roll E being immersed to some depth in the solution contained in C. The roll F is also supplied with a doctor and with pressure-screws.

Fig. 100.



The size-liquid is supplied from a receiver on the driving-side of the machine, and kept all the time at the same height in C. The paper becomes thoroughly impregnated and covered with it on its passage from the roll D to E through the trough C, and is again relieved from all superfluous solution (which returns into C) by the upper roll F.

On leaving this press, the pores of the paper should be well filled with size, but the surface should only be moist—not wet.

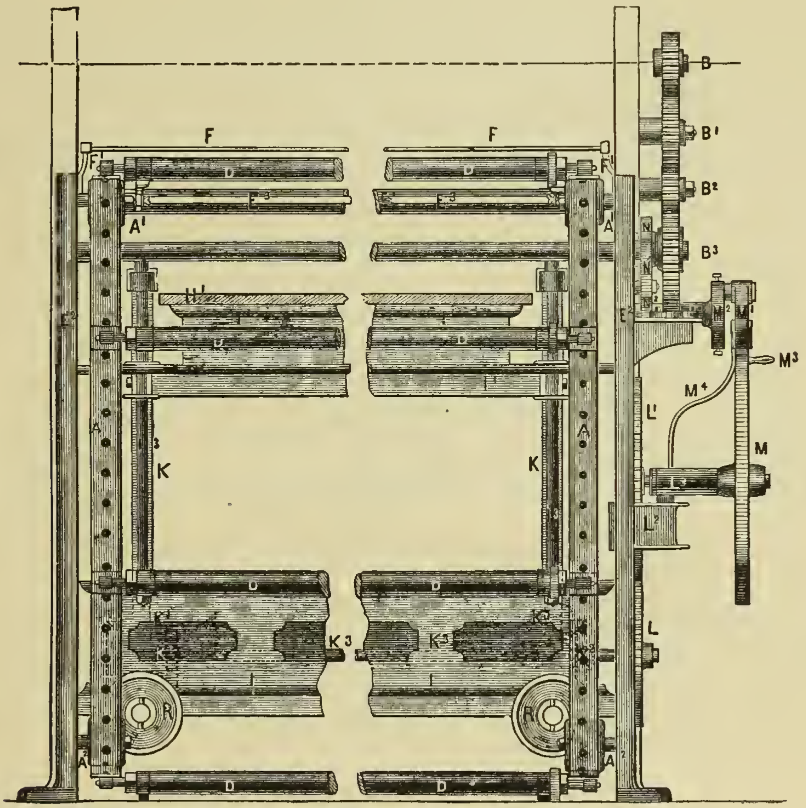
On the way to the cutter I, the paper is supported by the roll G and the angle-

roll H. The latter is fastened on a plank which extends across the machine, and is composed of two rolls of half the length of a full-sized paper-roll, meeting under an angle, the point of which is turned towards the cutter. This angle-roll H keeps the paper stretched and prevents wrinkles, by pushing it from the middle to both sides.

The continuous feed-cutter I is of the kind represented in Figs. 76 and 77. It has been selected because it runs without stops and starts, and delivers at all times a certain length of paper. If the sheets are not exactly of the same length, this is of little importance, as they have to be again trimmed after coming from the drying loft.

178. Kneeland's Lay-Boy.—The lay-boy K, on which the cut sheets are deposited,

Fig. 101.



is an ingenious machine, invented and patented by T. C. Kneeland, of Northampton, Mass., and deserves a full description.

Fig. 100 is a view of this lay-boy from the front side of the machine, without the frame on that side.

Fig. 101 is a view square across, as seen from the forward end.

Figs. 102, 103, and 104 are details which will be explained; the letters, designating their parts, correspond with the same letters of Figs. 100 and 101.

Two double leather belts A A, $2\frac{1}{2}$ inches wide and $\frac{1}{4}$ inch thick, are running over

the rolls A^1 A^2 A^3 A^4. The rolls A^4 are driven from the shaft of the revolving cutter-knife by means of four spur-wheels B B^1 B^2 B^3, and carry on their face a row of wrought-iron pins $2\frac{1}{2}$ inches apart, which correspond with holes of the same size and equally far apart in the belts A. These pins fill the corresponding holes of the belts while passing over or resting on A^4, and thus prevent them from slipping or changing their positions in any way, except when moved by the revolutions of the pulleys A^4. The web of paper C^2 descends through the cutter in the direction indicated by the arrow; it passes in front of the horizontal bed-knife C^3, over the wooden guide-board C^1, and hangs down from there in a perpendicular line. In our drawing, the length of one sheet has just passed the bed-knife C^3, and the revolving-knife C is in the act of cutting it off. The relative speeds and positions of the revolving-knife C and pulleys A^4 are so arranged that at the moment when a sheet is cut off, one of the rolls D has already struck it, the sheet folds over the roll and is carried along by it. These wooden rolls D rest in bearings, which are riveted to the belts A, as shown on an enlarged scale in Fig. 102, and every following one reaches the position of the preceding one when the revolving-knife C has completed one revolution. The belts A with their ten rolls D make, therefore, one revolution while the knife C makes ten. If the relative positions of the rolls D and of the revolving-knife C are not so that they strike the sheet at the right time, one of the spur-wheels B^1 or B^2 is removed, the pulley A^4 turned into the desired position, and the spur-wheel inserted again.

The sheets would leave the rolls D, over which they are folded, and drop on the floor if they were unsupported while they are carried forward. The first of their supports is the wooden roll E^1; its bearings are fastened in the frames E^2, and it is easily turned by the friction of the moving sheets. It is succeeded by flat pieces of wood E^3, extending also from one side of the machine to the other, and resting in the open bearings E, which form part of a flat casting bolted to the stands E^2, or, to speak correctly, to the pieces E^4 (see Fig. 102). All of these bearings E are never filled at one time, as a few wooden cross-pieces E^3 are sufficient.

Two brackets F^1, fastened to the stands E^2, carry an iron rod F, on which strips of felt, $1\frac{1}{2}$ to 2 inches wide, 18 inches long, and 6 inches apart, are suspended. These strips rest on the upper side of the sheets, while they are carried along on the rolls D, and assist in holding them flat in their place.

The construction of the heads of the rolls D is shown on an enlarged scale in Fig. 102, and side views are separately shown alongside of each head. These heads are of iron, and have a perfectly square part D^1 next to the journal. As soon as the rolls D reach the frames E, their square ends D^1 meet the corresponding flat strips D^2, which rest on flat pieces of wood E^4, supported by the iron angles E^3.

The square heads D^1 slide on those strips, preventing the rolls D from turning, until they reach, at about the middle of the frame, the rack G. Only one side of the machine is supplied with such a rack, bolted to E^4, and a casting G^2 of exactly the same dimensions, with a smooth top in place of the cogs of the rack, occupies the corresponding place on the other side.

A spur-wheel G^1 forms part of the head of the roll D at one end, and a smooth cylinder G^3, of the same diameter as the pitch-line of G^1, adjoins D^1 at the other end. The top of G and G^2 is slightly elevated above D^2 D^2, and, as soon as the spur-wheel G^1 and cylinder G^3 meet G and G^2, they mount upon them, and the square parts D^1, which have so far supported the roll, hang clear above D^2, and leave the roll D free to revolve.

The lower part of the sheet, on leaving the supporting pieces E^3, drops down on the pile of paper H, and the upper part is rolled off from D, while the spur-wheel G^1 turns on the rack G.

After the roll D has passed the rack G, its work is done, and it proceeds, supported only by the belts.

The upper part of the sheet folded over the roll D is always of the same length, independently of the size of the paper; it is equal to the distance between the bed-knife C^3 and the point where the roll D strikes it. That distance gives therefore the length of the rack G, but the latter can be shifted on E^4 to suit the varying lengths of the lower part of the sheet.

The paper is thus deposited in piles H on the loose boards H^1, which rest on the wagon I.

The wooden table, or top I^1 is bolted to castings I^2 on each side, moved up and

FIG. 104.

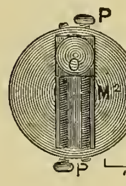


FIG. 103.

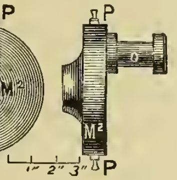
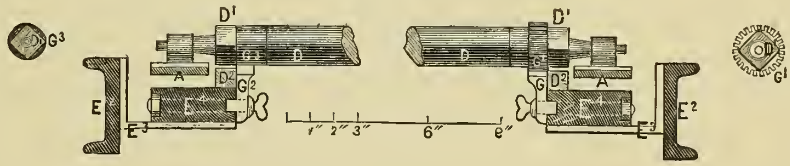


FIG. 102.



down by the screws K, and guided by the bolts I^3. The bevel-wheels K^1 and K^2, inside of the wagon I, turn the screws K, and are themselves set in motion by the shaft K^3, which extends beyond the frame E^2 on the driving side. The short shaft L^3, mounted on the bracket L^2, which is bolted to the frame, carries, besides the ratchet-wheel M, a spur-wheel L^1, which moves another one L, on the end of shaft K^3, and through the gearing already described—the platform I^1.

The principal shaft, which carries the pulleys A^4, moves also, by means of the spur-wheels N, N^1, and N^2, the crank-plate M^2, and with it the ratchet M^1 and the ratchet-wheel M.

The crank-plate M is shown on an enlarged scale in front and side view by Figs. 103 and 104.

The crank-pin O, which supports and moves the ratchet M^1, can be shifted in and out on the two screws P P by turning both of them, and thus can the stroke of the ratchet, and with it, the speed of the spur-wheels L and L^1, screws K K, and of the downward movement of the platform I^1, be increased or decreased. This is

necessary to suit the different thicknesses of the sheets, and it can be regulated so that the top of the pile of paper H, remains always closely under the rolls D, which deliver the paper.

When the platform I^1 has reached the lowest possible point, or the pile of paper H, has reached its utmost height, the wagon which runs upon four rolls R is pulled out from under the machine on the wooden rails R^1. Before the wagon is withdrawn, another platform must be provided, which may take its place for the reception of the sheets.

Iron rods are for this purpose laid into the two sets of brackets S, which are fastened to the frames; they support loose boards which form a table above the pile of paper H.

The wagon being run out, two men lift the boards H^1, with the pile of paper H, from the platform I^1 on to a truck, and forward it to an elevator or to any part of the mill.

The empty wagon is returned to its place, the ratchet M^1 put out of gear, and the ratchet-wheel M turned back by means of the handle M^3. A flat piece of iron M^4, fastened on L^2, has a fork at its upper end, and the ratchet M^1 hangs between its two prongs; while inactive or out of gear, M^1 is held suspended above M by resting on a pin, which has been put through two opposite holes in the prongs for this purpose.

By turning the wheel M backwards, the platform I^1 is raised up until it reaches the loose boards, on which the sheets have been dropped during its absence. These boards are thus lifted off from the rods resting in S; the latter are removed, the ratchet M^1 returns to its duties, and the platform or top I^1 begins to descend again.

179. Construction and Management of Drying-Lofts.—The trucks loaded with paper are usually taken to the hoister and forwarded to the drying-loft.

These drying-lofts occupy the upper part of the building next to the roof, and are constructed on the same principles as those in which hand-made paper used to be dried.

The paper is there exposed to the air until all the water contained in the size, with which it is impregnated, has been evaporated, and the remaining gelatine forms a hard coating.

This method is well known to our old paper-makers, and we shall content ourselves with a description of it as practiced in the New England letter-paper mills.

Light wooden framework, the posts of which are fastened to the floor and ceiling, extends in parallel rows all along the room. It serves as a support to wooden poles in horizontal rows, which, with the paper hanging over them, fill up all the available space from floor to ceiling, leaving only room for the circulation of the air. A passage around these frames is usually left along the outside walls of the building, giving access at the same time to the windows and shutters.

The paper is taken from the truck, with the boards on which it rests, and placed on a small table. A workman then takes, without counting, a package of about seven sheets from the pile, and folds it in the middle of its long sides over the cross-piece of a wooden T-shaped tool, resembling a rake without teeth. With this tool he raises

the package of paper or *spur* above one of the poles in such a way that the sheets remain hanging on it when the lifter is withdrawn.

It is evidently desirable that the poles or *tribbles*, which are made of wood, about $1\frac{1}{4}$ to $1\frac{1}{2}$ inches square, should not offer any sharp corners to the paper which is suspended on them.

The two upper corners are therefore usually rounded off, or the whole top is made round, while the bottoms remain flat and retain their corners.

The poles must also be kept perfectly clean, and as there may be some coloring substance in the wood, which, in course of time, might be extracted by the moisture of the paper, and thus taint it, they are in some mills, where superfine letter-paper is made, covered with a coat of white paint.

Rooms with high ceilings are inconvenient for this purpose, because the upper row of poles can only be reached with difficulty; high lofts are therefore mostly divided into two stories.

The paper is left on the poles until dry, and at a temperature of from 60 to 70 degrees Fahrenheit; the drying takes from three to four days. To produce this temperature artificially, whenever the atmosphere is too cold, wrought-iron steam-pipes are laid on or near the floor, along all the framework on which the poles rest. If the pipes are not very large (1 inch to $1\frac{1}{2}$ inch), several lengths are required for every frame, and they make up a large amount for the whole drying-room. One stream of fresh steam only should be admitted at the highest point of the system of pipes, and the latter should be connected with each other in such a manner as to lead the condensed steam to the lowest point, and back into the boiler.

It is also necessary that the air, which has become loaded with moisture, should escape and be replaced by a fresh supply. Hot air is capable of holding more water in suspension than cold air, and as it is also lighter it ascends to the top of the drying-rooms, and should be taken out from there while the fresh supply enters near the floor.

We have seen mills, where ordinary windows and shutters serve for both the ingress and egress of the air, and in many others they constitute the only openings for the admission of fresh air. A system of registers, through which the air would enter constantly, all round and near the bottom of the loft, would be preferable to the irregular streams, which are at long intervals admitted through windows.

Pipes or cylinders, from 8 to 12 inches wide, of galvanized iron, which serve as ventilators, are mounted on the roofs above the drying-rooms of modern mills. They are supplied with dampers, which can be opened or closed from the floor below by means of chains or ropes, and surmounted by galvanized-iron hats, which keep out the rain.

If these chimneys are well distributed over the drying-loft, if the admission and discharge of air are well regulated, and if, by the aid of steam, a moderate temperature is constantly kept up, the paper will be found to be uniformly dried when taken from the poles.

In saying this, we suppose that the paper has been uniformly soaked with the gelatinous solution. If it should have left the dryers in a damp or in an overheated state, it would absorb either too much or too little solution in the sizing-vat, and return insufficiently or too much sized from the drying-room.

The gelatinous solution impregnates the whole mass of the paper, though it is intended to cover only the surfaces with it. The water in evaporating is transformed into vapor or steam, carries with it the gelatine which it held in solution, and deposits it on the surface. But this can only be done if the drying-process is carried on slowly, at a low temperature; if the paper is strongly heated, the water or steam departs so fast that it cannot carry the gelatine along, it becomes solid between the fibres, and the paper will be brittle and poorly sized.

This difficulty is in a measure overcome by the use of a larger proportion of size. The faster the paper is dried the heavier must it be loaded with gelatine, to have enough for both, body and surface.

The paper, when taken from the poles, is bent in the middle, where it was folded over them.

It is therefore smoothed or *joged* out on a table, and all defective sheets which are found during this operation are taken out.

After the *joger* has straightened the paper as well as possible by hand, it is piled up again, and subjected to the pressure of a hydraulic or screw-press, where it becomes sufficiently smooth to be fed to the sheet calenders and other finishing machines, which will be described in a subsequent section.

In former times every sheet of writing-paper had to be dried twice in the lofts, once before and once after sizing, but the drying-cylinders obviated the necessity for the first one of these operations; and it is very natural that the paper-makers should also have tried to replace the second one by continuous machinery.

180. Drying in the Web.—The web, instead of being cut into sheets on the machine, is for this purpose conducted over a large number of rollers, while a stream of warm air carries off the moisture.

In England this is done by rows of skeleton drums or cylinders, of from 3 to 4 feet diameter, in each of which a fan revolves at great speed, independent of the motion of the cylinder, creating a current of air, which is carried off by ventilators on the top of the building. The surfaces of these drums, having only solid parts enough to give the necessary support to the web, do not prevent the direct contact of the air with the paper.

Steam-pipes underneath a floor of perforated, or partly open, cast-iron plates, extending as far as these drums in length and width, heat the air to the required temperature.

That temperature may be lower in proportion, as the passage of the paper over the ventilators is longer, or the more of them there are provided. Slow drying is essential to the production of a well and uniformly-sized paper, and the paper-machines have therefore been extended to an enormous length by the addition of large numbers of ventilating drums.

We have been informed that Mr. Cowan's mill at Valley Field near Edinburgh, Scotland, contains a machine, which is of such length that nearly one mile of paper has to be made, before the first sheet is obtained at the cutter. By far the larger portion of this mile of paper is wound around 384 ventilating dryers, which are divided into three rows, placed one above the other. The paper, after having passed through the size-vat and press, is guided over one row of drums, returns all the way back over the second one, and departs finally to the calenders and cutter over the third one. On its passage over these drums it is guided between 6 rows, 3 above and 3 below the paper, of tapes or ribbons, about one inch wide, which are supported and running in the same way as the felts.

These tapes will sometimes break, and it is important that the whole drying apparatus should then be quickly stopped to repair them. The machine is therefore divided into a number (10) of divisions, each one of which is watched closely by a machine-tender, and provided with the means of stopping all of the drums.

The large expense caused by the erection and operation of such a drying apparatus seems to have prevented its general introduction. We know of only one mill in the United States where one of them, and that with a moderate number of ventilating-drums, is used. Several inventive paper-makers have, however, tried to replace them by simpler constructions, some of which are in successful operation.

At a mill in New England which manufactures Nos. 2 and 3 flat-cap, the paper, after leaving the dryers and slitters, passes through a size-vat and press of the usual form, but supplied with a very concentrated solution of gelatine, and from there directly over three copper drying-cylinders heated with steam. The paper leaves them perfectly dry; but the quantity of size which has to be used to make up for the fast drying is so large that it increases the weight of every ream by about 2 pounds. 2 pounds of paper are worth more than 2 pounds of the gelatine used, and thus pay fully for the expense of the sizing material.

This expeditious way of drying would probably not suit for better grades of paper, but it proves quite satisfactory for the qualities to which it is applied.

It is generally conceded, that it is advisable to at least dry the paper in the air, at a moderate temperature, long enough to *set* the size, when the rest of the water may be evaporated on steam-heated cylinders.

Some of the machines of the Seymour Paper Company, at Windsor Locks, Conn., are provided with an apparatus constructed on this principle.

The machine-room, which is very high, has a flat ceiling, and between it and the dryers and sizing-vat, are suspended on wooden frames three rows of light wooden rolls, over which the paper passes to and fro in nearly horizontal lines. A common belt passes over the ends of the last rolls of each row on the driving-side, and sets them in motion. Steam heating-pipes are fastened near the ceiling and below the course of the paper, to prevent the escaping steam from condensing and dropping on to the paper under it.

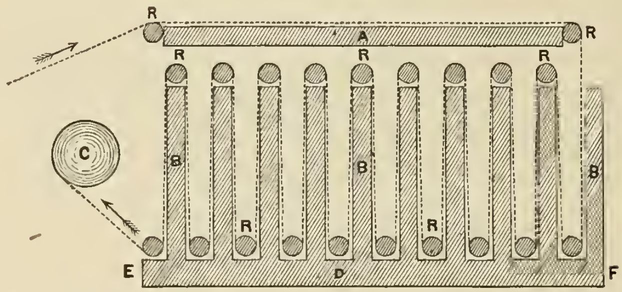
The web passes through the usual size-vat and press, then over these rolls above the machine, and lastly around three steam-heated cylinders, which finish the drying.

It is to be supposed that the location of the drying arrangement, above the machine, has been selected on account of the available room, and because the heat of the dryers might be further utilized for drying the sized paper. But the air which ascends from the drying-cylinders, already loaded with water or steam, is hardly capable of taking up any more from the sized paper above, which cannot possibly be as well dried as if freshly heated air had swept over it.

This method can hardly be recommended for fine surface-sized papers, but may improve medium qualities, which have also been sized in the pulp, by imparting greater strength to them, and producing what is called a *crackling* paper.

An ingenious American paper-maker has constructed a drying arrangement for the use of hot air alone, which, for compactness and simplicity of design, appears to be superior to all others. A cut, showing a section through it lengthways at $\frac{1}{100}$ of its real size, is represented in Fig. 105. The paper is indicated by dotted lines, and travels in the direction shown by the arrows.

Fig. 105.



Coming from the size-vat and press, it passes first over the top of the apparatus, facing a flat wooden box A. It then passes down to the bottom of the open space between two of the partitions B, up over the next one, down and up again, until it arrives at the reels C, where it is wound up. The flat wooden box D lies on the floor, carrying all the upright wooden partitions B B, and communicating with A on the driving-side of the machine by means of wooden flues. A, B, and D are as wide as the machine, and the surface of A and all the sides of B which face the paper are perforated with numerous holes. Steam circulates through coils of heating-pipes in D, entering at the end E, while a stream of fresh air is constantly blown into D, by means of one or more fans, from the opposite end F. These fans may be situated anywhere, if they are only connected with D by pipes. The air becomes heated in contact with the coil of pipes in D, and finds its only outlets through the holes on the surfaces of A and B, where it meets the paper and escapes on both sides. One common belt passes over the back ends of a number of the rolls R, driving them thereby, and assisting the reels C in pulling the paper through.

The number of partitions B may be increased or decreased. At the inventor's mills they are about $7\frac{1}{2}$ feet high and 8 inches wide, and a surface of from 400 to 500 feet length of paper is offered all the time to the heated air.

The paper might also be guided so as to enter the partitions B, where it now leaves them, and then pass through calenders and reels at the forward end. It has evidently been the aim of the inventor, to build as cheap a drying apparatus as possible; and any millwright supplied with boards, pipes, fan-blower, and paper-rolls, should be able to put up one of the kind described. We suppose that from the same motives of economy, the reel, which requires driving power, has been placed near the sizing-vat, to prevent the necessity of extending the gearing on the driving-side to the far end.

We have been informed that the flat-cap papers made by the inventor on this machine are valued as highly in the market as the same grades of loft-dried ones from other mills.

181. Merits and Demerits of Different Systems of Sizing and Drying.—Whenever surface-sized paper is dried in the web, it must be stretched or held in tension while passing through the necessary apparatus, of whatever construction it may be. This tension prevents the free contraction which is one of the principal causes of the superiority of loft-dried papers. The fibres approach each other and intertwine more thoroughly, and thereby make the paper stronger and tougher when unrestrained; but this tendency is entirely checked when it is pulled over a machine.

All the drying arrangements described in the foregoing pages, are in this country used for the cheaper grades of writing and book paper only, while all the finer ones, especially letter-paper, are dried in the loft.

Paper, made and sized on a machine of the kind represented in Fig. 99, is never touched or handled until it reaches the drying-loft, and all the labor there consists in hanging it up, removing it again from the poles, and *joging* it.

Since the introduction of sheet-calenders, loft-dried paper can be finished nearly as cheaply as paper in the web or rolls.

If the drying is done slowly, as it should be, the automatic drying apparatus must be very long, and probably would cost more than the loft with its fixtures.

The increased expense of drying by the loft-process is—at least with the finest grades of paper—fully compensated for by the improvement of their quality.

The writing public of Germany and France use the engine or resin-sized paper furnished by the mills of those countries. None, or very little surface-sized paper is at present manufactured there; but we have no doubt that its superior qualities, if it were once introduced, would soon be appreciated and create a great demand for it.

Considering—

1. That with the latest improved machinery, surface-sized paper can be produced with very little more labor than engine-sized paper;
2. That softer (and consequently cheaper) stock, if coated with gelatine, will furnish as strong a paper as harder stock sized with resin;
3. That the consumers pay for the gelatine in the increased weight of the paper;

we conclude that surface-sized paper can be manufactured at about the same cost as pulp-sized paper.

SECTION VII.

Finishing.

182. Finishing Common Paper.—Paper of inferior qualities, such as news-print, wrapping, &c., is taken from the cutter to the finishing table, and there counted into quires of twenty-five sheets for printing-paper, and of twenty-four sheets for other kinds.

The girls who lay the sheets, as they come from the cutter, throw out all the imperfect ones which they may see, and the finisher inspects them again while counting. If the machine-tender is careful, and does not allow bad paper to be cut, and if the cutter-girls and finisher do their duty, this simple system of sorting is sufficient.

For the sake of easy handling, the sheets are folded by the finisher in the middle of their long sides, while he is counting them, into quires of twenty-four or twenty-five sheets. To obtain packages of uniform thickness, these quires should be laid on each other, so that the open sides and the folded or closed ones alternate, or that the position of every quire is the reverse of the preceding one. This is necessary because the quires are thicker where they are folded than at their open sides.

Forty quires, or two reams, of light paper, and twenty quires, or one ream, of heavy paper are usually packed together by simply covering them with strong wrapping-paper, tied with hemp or Manilla twine. Such bundles are light enough to be handled by one man; they are easily made and opened, and as they are sold by gross weight, the paper-maker does not lose the packing material, which is, at the same time, of some value to the purchaser.

The paper shows a better surface, and can be packed more neatly if it has been well calendered or pressed. It may, for this purpose, be subjected to the action of an ordinary press, but it will be improved even by its own weight, if the paper is piled up over night in high columns, covered with boards, which are held down by heavy pieces of stone or iron.

One good finisher can easily count, fold, tie out, and weigh 3000 pounds of newsprinting-paper per day. Mills, which confine themselves to this and similar grades, require therefore, a comparatively small room for finishing, and it should always be situated on the same floor with and adjoining the machine-room.

For all the better qualities, such as letter or fine book paper, the finishing-room is of more importance, as it contains the super-calenders, ruling, cutting, stamping machines, and presses.

183. Plate-Calenders.—Not many years ago, before the present system of glazing paper in super-calenders was introduced, it was first cut into sheets, and then passed through plate-calenders.

The sheets were laid singly between copper or zinc plates or press-boards until a pile or package of about twenty or thirty of them, alternating with plates, was formed. These packages were exposed to a strong pressure between iron rolls, which they passed and repassed until the surface of the paper was sufficiently glazed. If a highly-calendered surface was required, the plates had to be changed frequently, and the paper relaid between them.

The best plate-calenders consist of two press-rolls with tables on both sides, inclining slightly towards the opening between the two rolls. The operator lays the package of plates and paper on the table at the front side, and pushes it in far enough to be taken hold of by the rolls, and passed to the table on the back side. Before the package is quite through, it strikes with its forward end against a movable slide, which reverses the motion of the rolls by means of a leverage and two sets of pulleys and belts. The rolls, which have not fully released the plates from their grip, thus return them to their original position. The weight of the upper roll is increased in the usual way by screw-pressure or by levers and weights.

A considerable number of hands are required to lay the paper between the plates, but the largest expense is caused by the plates themselves. A great many and of different sizes must be kept on hand to suit the various sheets, and they are necessarily flattened out, and become cracked and useless in the course of time. The *plating* of paper in these calenders or *platers* requires a great deal of power, and is altogether a very costly operation.

Among all the mills which manufacture fine papers in this country, we have only found one where plate-calenders are yet used. The manager of that mill understands thoroughly how to work these *platers* as economically as possible, and has established an enviable reputation for his paper, but the almost total abolition of this system proclaims, beyond doubt, the victory of the super-calenders.

The only advantage over super-calenders which platers are credited with, is that they impart a perfect finish to the paper, without pressing it into as thin sheets as the former.

Metallic plates transfer some of their substance in infinitesimal particles to the paper between them, which thus receives a bluish tint between zinc and a reddish one between copper plates.

Heavy, coarse paper, which is too thick and stiff, to move around the rolls of the super-calenders, must from necessity be glazed in the old way.

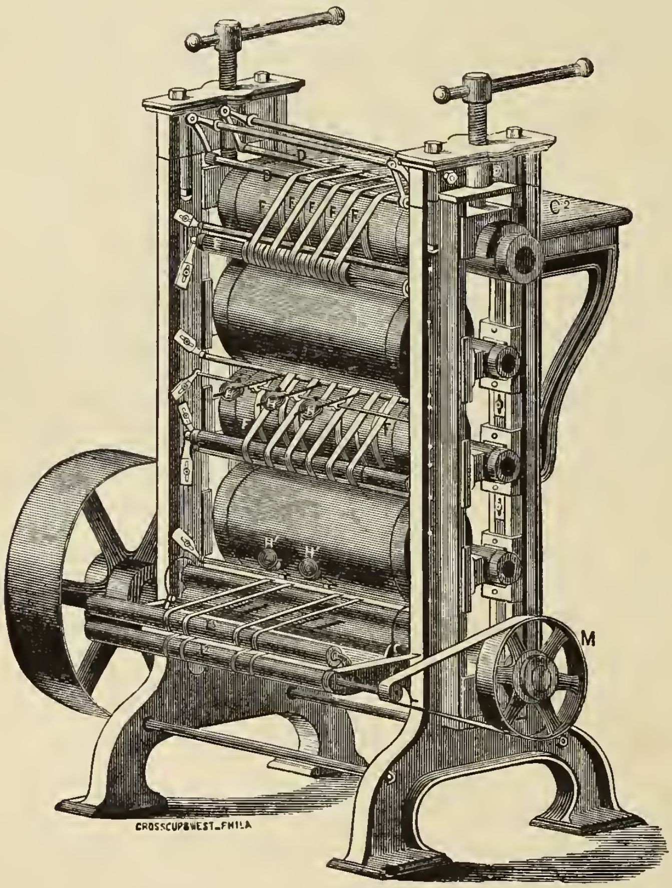
184. Sheet Super-Calenders.—The following Fig. 106 is a perspective view, Fig. 107 a section, and Fig. 108 a section of the three lower rolls and fixtures on a larger scale ($1\frac{1}{2}$ inch per foot) of a stack of sheet super-calenders, built by the Holyoke Machine Company at Holyoke, Mass.

This stack consists of three chilled-iron rolls A A^1 A^2 and two paper-rolls B and

B[1]. The paper-rolls consist of numerous sheets of paper which have been slipped on an iron shaft, and compressed into a solid body held between iron heads. Paper which is made of the strongest fibres answers best; those represented by B and B[1] are of fine Manilla paper, and have from 200 to 400 sheets in every inch of the length of the roll. They are put on the shaft and subjected to a hydraulic or screw-pressure of 500 to 1000 tons, until they form a compact mass, which is then inclosed between collars of a particular construction.

These collars are forged round, but cut open, so as to form two half circles, which exactly fit into recesses in the shaft. The heads being in their places, the half collars

Fig. 106.



are laid into the adjoining recesses, and rings or bands are shrunk or driven over and around them, which hold the two halves tightly together.

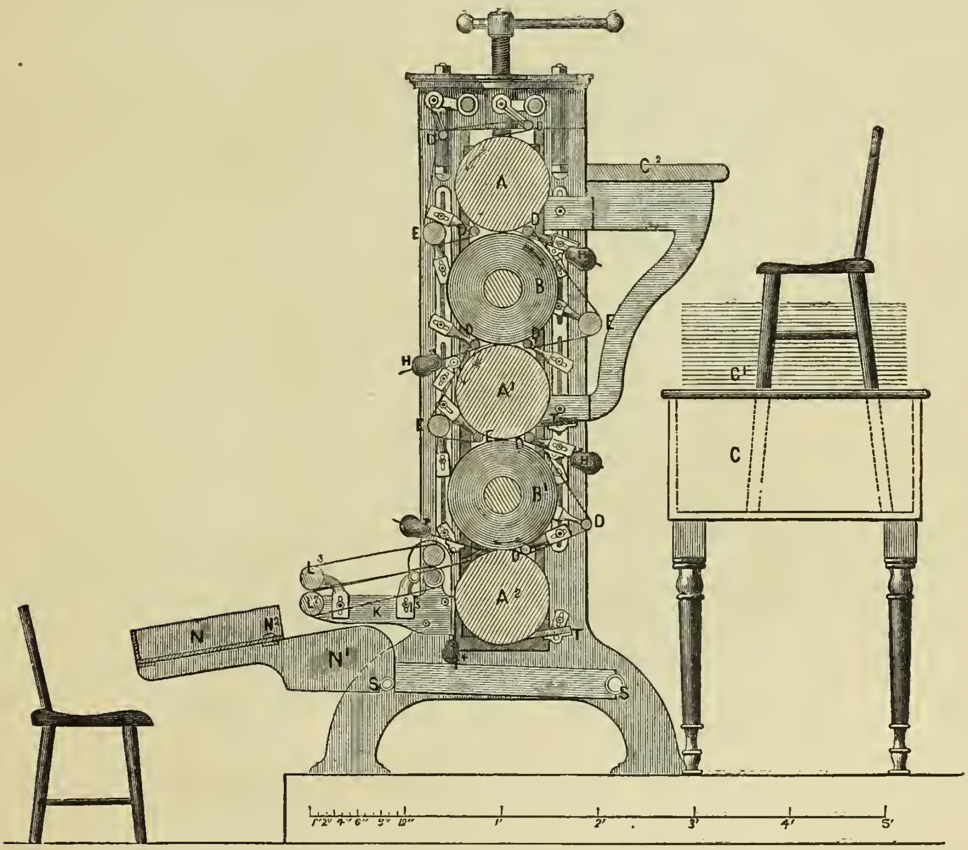
The collars in the recesses cannot move lengthwise on the shaft, as long as they are surrounded by the ring.

Some machinists have found that the paper will produce a harder roll, or will be better compressed by screws than by hydraulic pressure. The screw-pressure is

applied through four upright, stout, threaded bolts, between which the roll is placed in the centre. A follower, bearing on the paper and sliding in these bolts, is gradually pressed down by the nuts, which are turned singly and in succession by means of a long iron lever or wrench operated by several men.

This operation requires more labor, and is consequently more expensive than the application of hydraulic pressure; but it acts more gradually, preventing the elasticity, which is once overcome, from exercising any influence, and as there is no leakage—consequently no diminution of pressure—it may prove practically the best method, as the same amount of pressure may be applied with either system.

Fig. 107.



The paper being thus formed into a solid mass, it is turned and ground like iron rolls, and acquires a surface resembling that of glazed pasteboards.

The pressure exercised by the weight of the calender-rolls is increased by screws on top of the stands.

A pile of paper C^1 is placed on the table C, gradually taken up by a female operative, who may sit on the chair alongside of it, and placed on the platform C^2,

which rests on brackets fastened to the stands. The sheets are then forwarded, one by one, upon the roll A, so that they follow each other in an uninterrupted train.

The rolls D D are made of one-inch wrought-iron tubes with cast-iron heads, and the larger ones E E are of wood. The cast-iron bearings are bolted to the stands, so that their positions can be changed in every direction. Three iron rolls D and one wooden one E, are situated so that endless bands F, which run over them, cover about one-half of the circumference of the roll A; the sheets are pushed in between the bands and the roll on top of A, held by the former to the surface, and carried far enough to secure their passage between A and B.

It is now necessary that the paper should leave the roll A and follow B, and in ordinary calenders the machine-tender removes the sheets from A and guides them over B; but in our sheet super-calenders, the human fingers are replaced by iron, or rather steel, ones.

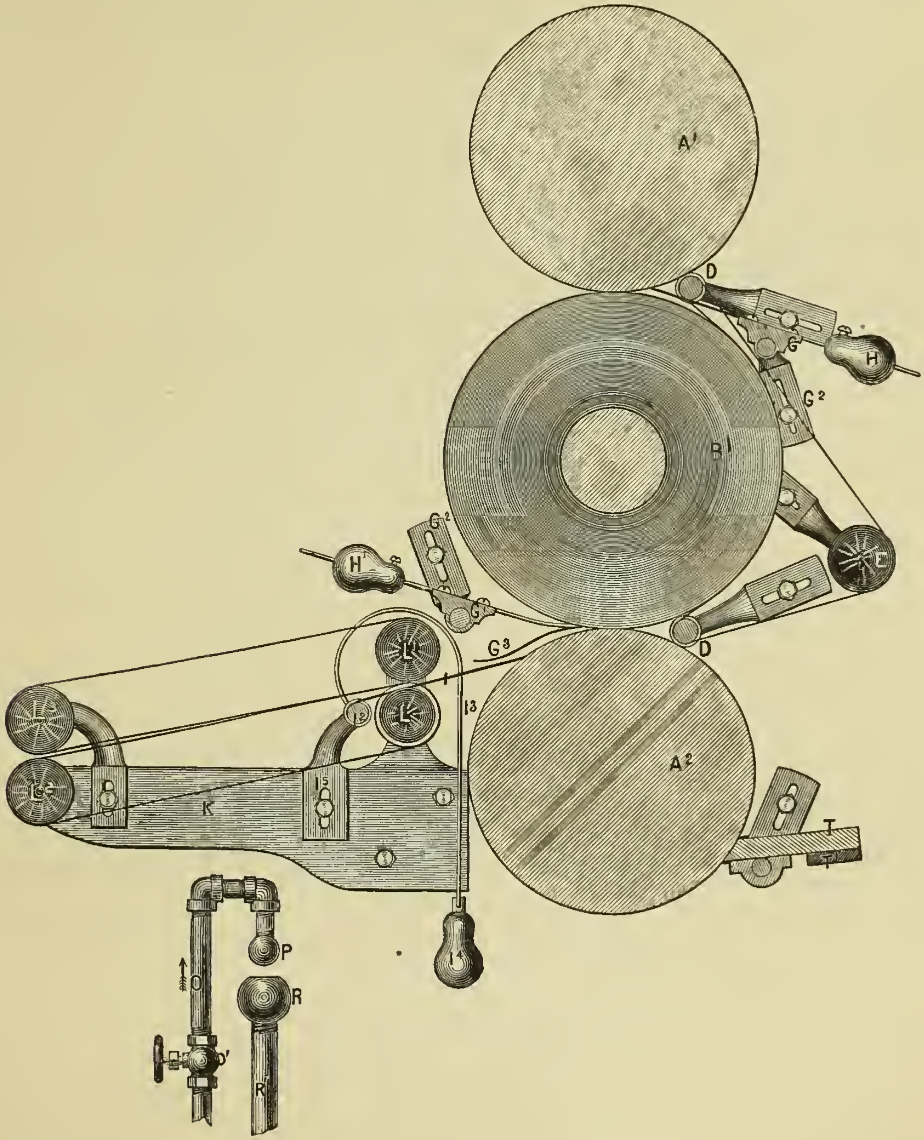
A small iron casting G (Fig. 108) rests on a shaft, which is suspended in bearings G^2, fastened to the stands, like those of the rolls D D. A strip of steel, $\frac{1}{16}$ inch thick and $\frac{3}{4}$ inch wide, with a movable cast-iron weight H on the end, is sunk in and fastened on the top of G by means of two screws. The forward end of this strip or finger is made to bear slightly against the roll A^1, just enough to prevent the paper from following it any further. This pressure, if it may be so called, can be regulated nicely by the position of the weight H, and the points of the fingers are flattened out to fit on the surface of the roll A without cutting it. These fingers are only resting on their shafts; they are not fastened, and must be occasionally moved sideways along the face of the rolls, to touch every part of their surface for an equal length of time, and thus wear it uniformly. The length of the rolls in our drawing is 28 inches on the face, and two or three of these fingers are applied to every one, according to the width of the paper.

The sheets, being thus prevented from following the roll A any farther, are transferred to the surface of B, and kept to it by another set of endless bands, running over two iron rolls D and one wooden roll E. Five or six of these guide-bands F (Fig. 106), $1\frac{1}{2}$ inches wide, of strong well-woven cotton, sewed together at the ends, run over every set of rolls D D and E, and are tightened, if they become slack, by moving the bearings of the rolls D and E further out.

Each one of the rolls A B A^1 B^1 is supplied with fingers and guide-bands; the sheets are safely passed through the calenders and leave above the lower roll A^2. To the forward ends of the two fingers, applied to the roll B^1 and fastened on castings G^1, are riveted pieces of thin sheet-copper G^3 as wide as themselves ($\frac{3}{4}$ inch), which can be bent into any desired shape. The bearings I^5 bolted to the brackets K, which are bolted to the stands, carry a shaft I^2, to the flattened parts of which are riveted five other steel fingers I for the support of the paper on leaving the rolls. The bent wires I^3, fastened to the ends of the shaft I^2, carry the weights I^4, and press the fingers I sufficiently against the roll A^2.

The sheets, on leaving the roll B^1, have no choice of way, but are guided between the copper strips G^3 and the fingers I to the wooden roll L. Bands of the same kind as those running over D and E pass over the rolls L–L^2 and L^1–L^3; the sheets enter between them, are carried through and deposited in the box N, being at this place

FIG. 108.



carefully watched and sorted by a female operative seated on the chair (Fig. 107). The roll L^2 is set in motion by the pulley M on the shaft of roll A^2 (Fig. 106); L is driven from it by the bands, and moves in its turn L^1, which rests on it, by friction.

Wooden doctors T, carried in the same kind of iron brackets as the rolls D and E,

prevent any impurities or pieces of paper from going round on the rolls A^1 and A^2. They are pressed against these rolls by the weight of pieces of lead, which are fastened to them.

The receiving-box N (Fig. 107) can be moved in and out on the supporting wooden brackets N^1 to suit the various lengths of sheets, and is only held in its place by a half-round board N^2 on top, which forms a clamp with a corresponding board below. The boards N^1 are not fastened anywhere, but simply notched out to fit the two rods S, on which they can be shifted sideways, and which hold them in their places.

The sheets leave the calenders loaded with electricity, produced by friction; they cling to each other as if they were pasted together, and paper-makers know how difficult it is to separate and lay them. It is necessary to draw off this electricity, and it can be done in a very simple manner by steam. A steam-pipe O (Fig. 108), ending in a goose-neck and the horizontal pipe P, is placed in the middle, between the brackets K. The pipe P is about two feet long, parallel with the calender-rolls, and has a row of small holes on its lower side, like a shower-pipe; a tin funnel or a larger pipe R, open on top, and situated below P, extends a short distance beyond it at both ends, catches all the water which accompanies the steam-jets, and discharges it through R^1. The steam rises up to the sheets as they pass over the rolls L and L^2, depriving them of their electricity, and its quantity can be regulated by the valve O^1.

The persons who shift the paper into the calenders from the platform C^2 are provided with rubber thimbles, to prevent the sheets from adhering to or being marked by their fingers.

The driving-roll A^2 of this stack makes about 80 revolutions per minute, and the sheets pass through it nearly as fast as if the paper were in rolls or web.

If a high polish is desired, the sheets are passed several times through one or more of these calenders; and the fact that nearly all the letter and other fine paper, made in the United States, is glazed in this way, proves their efficiency.

185. Transfer of the Paper from the Machine to the Web Super-Calenders.—Sheet calenders are only necessary if the paper has been sized on the surface and dried in sheets; but if it has been sized in the engine or on the machine, but dried in the web, it can be glazed in web calenders.

After the paper has been cut lengthways by the slitters on the machine, it must be wound up on reels which can be taken to the super-calenders.

The reels of the paper-machine are for this purpose filled with paper in the ordinary manner, and wound off on other reels, the shaft of which is supported by the machine-frames, and driven by means of the usual friction arrangement, so as to reduce its speed in proportion with the increase of the diameter of the roll of paper.

The reels, which are slipped on this shaft, consist of two cast-iron spiders, bored out as large as the thickness of the shaft, and they have, including the usual six wooden caps, a diameter of from 6 to 8 inches. Every spider has a projection, fitting

a like one in an iron collar on the same shaft, and forming a clutch with it. Whenever paper is to be rolled up, these collars are put in contact with the spiders, fastened to the shaft with set-screws, and thus turn the reels.

The super-calenders are wide enough for the width of one sheet only; the two or three trains of sheets cut by the slitters must therefore be rolled up on as many separate reels. If the paper on the machine has, for instance, been cut into three widths, the shaft must be supplied with three separate reels, the ends of which adjoin each other. As soon as they are full, the collars or clutches are loosened, the reels slipped off, and put on a shaft of the same diameter, on the frame of the super-calenders. Another set of empty reels is put on the shaft, which rests on the machine-frames, and filled up again as before. It is evident that a great number of these portable reels must be kept on hand.

186. Web Super-Calenders.—Web super-calenders are, like sheet super-calenders, composed of chilled iron and paper-rolls, but the paper is guided through most of them by hand, though some have been lately built with guide-bands and fingers, which take the paper through without any assistance. A stack of that kind, as built by the Rice, Barton & Fales Machine and Iron Company, Worcester, Mass, is represented in Fig. 109.

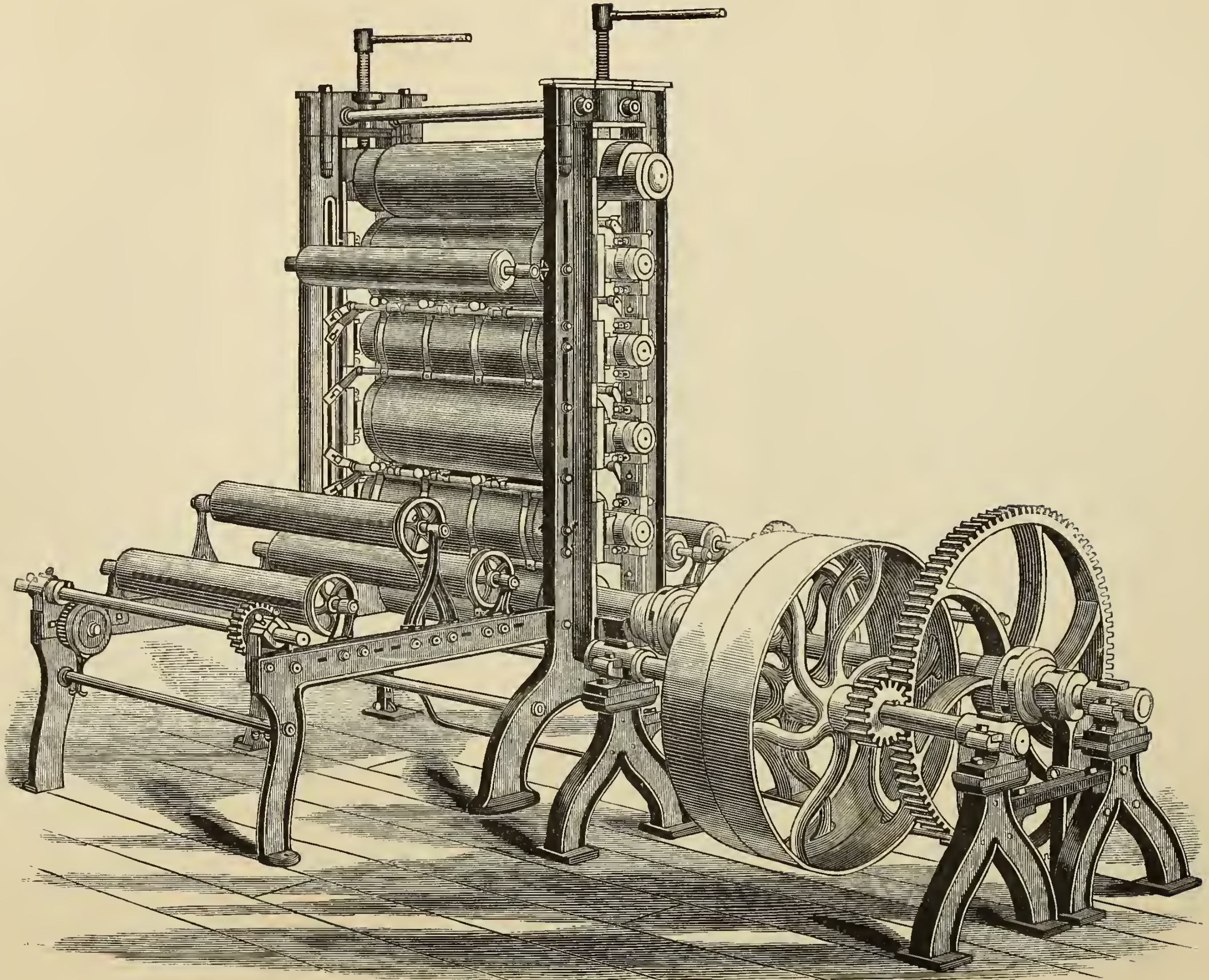
The two bottom rolls, the top roll, and the third roll (counting from above) are of chilled iron, and the second and fourth rolls of paper.

A heavy roll is required on top to give pressure by its weight. The paper rolls must be large, because they would otherwise soon become too small through wear and tear and consequent grinding and turning, and the bottom roll must be strong and large to support the weight of the whole stack. The paper rolls are frequently damaged by the doubling or rolling up on them of pieces of paper, or by accidents, and show high and hollow places, which mark the paper. It is not desirable to turn them off whenever they are slightly damaged; and it is for this reason that the two bottom rolls are of chilled iron. The paper passes through them after it has gone over all the paper ones, and their hard surfaces, under the pressure of the whole stack and of the screws, smooth out again any marks which may have been made by slightly damaged paper rolls.

The shaft on the forward end of the calender-frame (Fig. 109) carries the reels filled with paper, and the spur-wheel on it gears into another one, which is supported on the frame, but shown at the opposite end. A friction-pulley—to the surface of which a leather band is pressed by means of tightening screws, or by weights, attached to the loose end—is connected with this lower spur-wheel, and gives, by means of the upper spur-wheel, the necessary resistance to the shaft and reels. If the friction-pulleys were placed directly on the reel-shaft, it would be necessary to remove the leather bands whenever the shaft had to be taken off to change the reels.

On the same frame with the reel-shaft are seen three other rolls, likewise supplied with friction-pulleys, under and over which the paper is taken before it is put over another carrying-roll higher up, and into the stack between the two upper rolls.

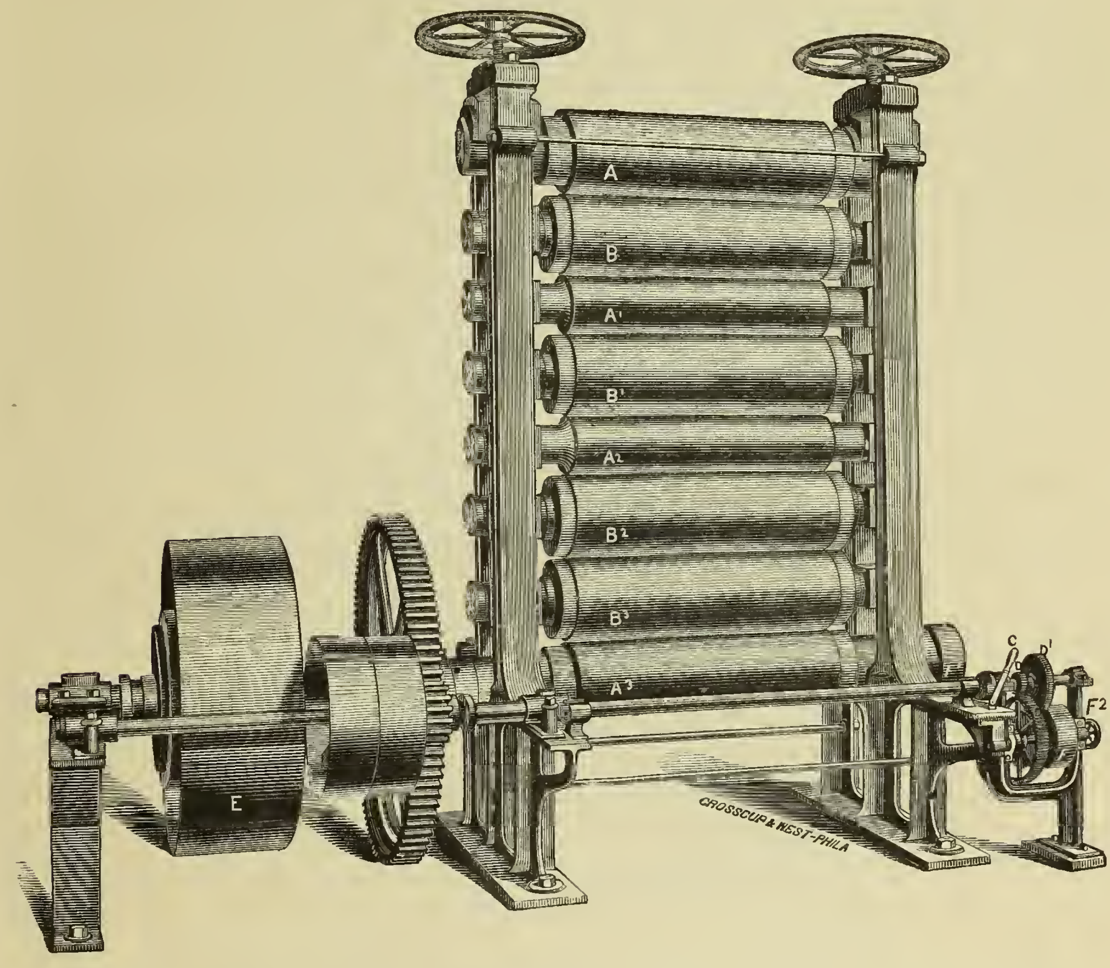
Fig. 109.



This circuitous route is necessary to straighten the paper and pass it into the super-calenders without wrinkles.

The stack is supplied with guide-bands and fingers, like sheet super-calenders; the paper passes through without assistance until it leaves between the two lower rolls, is thence taken by hand over three rolls, disposed like those shown on the front side, and wound up on the receiving-reels.

Fig. 110.



The stack of super-calenders represented in Fig. 110 has been built by Messrs. Pusey, Jones & Co., Wilmington, Del. It has four chilled-iron rolls A A^1 A^2 A^3, four paper rolls B B^1 B^2 B^3, and is set in motion by a friction-pulley E, the rim of which is lined inside with wood and fitted to a slightly conical iron pulley, which can be easily pulled out or pushed in by means of a coupling and lever.

The shaft, on which the calendered paper is wound up, is geared in an improved manner. It is driven from the pulley F^1 on the shaft of the lower roll A^3, by means of pulley F and spur-wheels D D or D^1 D^1. The two sets of wheels D D and D^1 D^1 are of different sizes, and enable the operator to pass the paper through the calenders with

either of the speeds given by them. The friction, through which alone the pulley F moves the shaft on which it runs, can be increased or reduced by a few turns of the hand-wheel F, in the same manner as that of the reel-shafts. The shaft on which the paper is rolled up, can easily be lifted in or out, as it carries no wheels or pulleys, and is connected with the gearing through a simple coupling controlled by the lever C.

The great pressure that is occasionally put upon the rolls, by means of the screws provided for the purpose, would tend to break the stands or frames. To prevent this, strong rods are placed in recesses in the frames, which connect the cap or top with the bearings in which the lower roll runs, so that the entire strain comes upon the rods, which, if broken, could be easily replaced, and no other part of the machine would be disturbed.

187. Attachments and Disposition of Super-Calenders.—Sometimes a cutter is attached to the super-calenders, and the polished paper is cut in sheets as soon as it leaves the stack.

Some papers, however, must be taken several times through the super-calenders, while others only once; and it is therefore more convenient to have the cutter independent of them. It can hardly be of advantage in any case to connect the cutter directly with the super-calenders, as the latter may run with much higher speed than the former.

The super-calenders represented in Fig. 109 are provided with tight and loose pulleys and with a coupling on the large spur-wheel, by means of which they can be stopped or started at will. These ordinary couplings must be constantly held together by force, slip out sometimes, and are a source of trouble and irregularities.

The *friction-pulley* represented in the following Fig. 111, invented and manufactured by Messrs. Volney W. Mason & Co., Providence, R. I., is frequently used and recommended for super-calenders, as well as for any other machinery which must be frequently stopped and started without any alteration in the motive power.

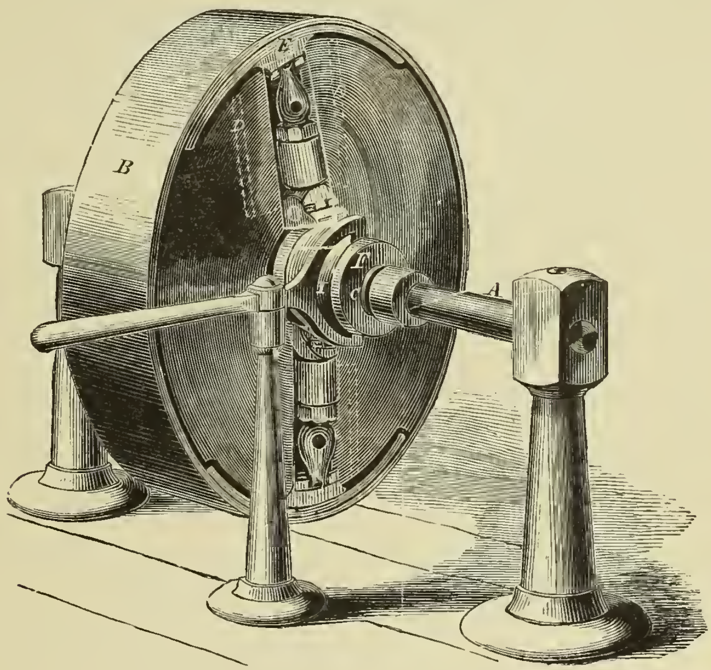
The sleeve or thimble F is operated by a lever, and slides on a key on the shaft A. A loose ring I is put in the groove of the thimble F, and connects with the fork of the lever by two projections or ears. The segments E, of which there may be two or four, according to the size of the pulley, are carried on F by arms, movable in toggle joints or hinges. The length of the arms can be increased or decreased by means of screws.

While the shaft A has no work to do, the inside of the rim of the pulley B does not touch the surface of the segments E, and the arms, which carry them, form an angle. But as soon as the shaft A is to be put in operation, the sleeve F is pushed against the plate D of the pulley B as far as possible, the arms will then form a straight line, the segments E are pressed against the rim of the pulley and compelled by friction to move around with it. As the arms are then standing square to the shaft A, there is no power exercised to push the sleeve F back—an advantage which this construction has over many other friction-pulleys. The inventors prescribe the following method for adjusting the friction:

"The friction-pressure may be equally adjusted by placing the centres of the segments E E horizontally; then place a strip of stiff paper between the centre of each segment's friction-surface and the inside of the pulley when the thimble is unshipped; then, while holding one strip of paper in each hand, have the thimble moved slowly toward the plate D, and notice which strip tightens first; then turn the screw of toggle joint to regulate until the pressure is alike on each segment, and sufficient to drive without slipping; then *tighten the check nuts firmly* against the joint. The thimble F should *always ship close up against the plate* D, as the toggles then just pass their centres, holding in themselves without any end pressure on the thimble, when shipped in to drive."

Buffers.—The paper calender-rolls require frequent grinding or buffing. This can be done while they are running, by an attachment to the frames, which carries an emery roll, moving laterally while being pressed against the calender-roll and revolving with different speed. The grinding-roll is an ordinary flanged pulley, the face of which is covered with a paste of resin and flour of emery. Buffing machines which work on this principle are used by many manufacturers, and answer the purpose.

FIG. 111.



Super-calenders are always built narrow, not over 36 to 42 inches, for the width of one sheet only; while the machine makes two or three trains of sheets at one time.

It is certainly possible to add super-calenders directly to the machine, but long rolls would then be required, which could hardly fail to spring in the middle if sufficiently pressed on the ends. They would also be more liable to be injured in the machine, as they cannot be stopped so suddenly and watched so closely, nor could they run as fast, as in an independent stack.

When plate-calenders used to be the only means of giving a high polish to the

paper, it was considered very desirable that calenders should be invented by which the paper could be finished on the machine; but our present super-calenders are so simple and require so little labor, that the comparatively small additional expense, caused by them, is fully compensated by the convenience and the advantages which they offer.

The cutters used for calendered paper are the same as those used on the machine, and they may cut two or three reels at one time, in the finishing-room as well as in the machine-room.

188. **Ruling-Machines.**—Nearly all the letter and blank-book paper must be ruled. In former times the lines were frequently pressed into the paper, like water-marks; but such lines are indistinct, weaken the paper, and destroy its uniformity.

Since ruling-machines have reached their present state of perfection, they exclusively are used for this purpose.

One of these machines, which has been built by the Holyoke Machine Company, of Holyoke, Massachusetts, is represented on Plate V by a plan in Fig. 1, and by front and side elevations in Fig. 2. The front elevation (Fig. 2) is shown without the front side frame.

The canvas apron A, which is supported by the board A^5, receives the sheets from the hands of an attendant, who furnishes them from a pile on an adjoining table. This apron A is kept stretched by the weight of the roll A^2, which is suspended on two levers turning in A^4, and by the stretch-roll A^1. The roll A^3 presses it against the wooden cylinder B, from which it receives its motion by friction.

The dotted lines B^3 B^3 indicate the belt by which the large driving-pulley on the shaft of the cylinder B, and with it the whole machine, is set in motion. This motion can be arrested or started by means of the coupling, which connects the loose pulley B with the shaft, and is easily thrown in or out of gear by the lever B^2.

Cotton threads, made endless by having their ends tied together, run, about 2 inches apart, over the cylinder B and the rolls C^1 and C, and another set of such threads moves on the upper part of the cylinder B, and over the rolls C^1 D^2 D^1 D, back to the starting-point.

These rolls rest in brass brackets, which are fastened to the frames in such a way, that their positions, and with them those of the threads, can be adjusted. One of the rolls of each set has narrow channels turned into its surface, wherein the threads run, and whereby they are kept in their places.

The sheets proceed with the apron A until they leave it at A^3, and enter at D, between the two rows of endless threads just described, which carry them over a part of B and over C^1 and C, where they leave for the second cylinder E. This cylinder E is of the same dimensions as the first one B; it rests in the bearings E^1, and its pulley E^2 is driven from B^1 by a cross-belt. One set of endless threads runs over a part of E, and over the rolls F^3, F^2, F^1, F, and another one winds its way over the cylinder E, and the rolls G^1 and G (Fig. 1). The sheets, coming from C, enter between these two rows of threads at F, pass with them over E, and leave them again at G^1.

We shall first follow the paper on its course through the whole machine, and then explain the manner in which it is ruled and cut, while passing over the cylinders B and E.

The sheets leave the threads at G^1, and are carried by the apron I from H^2 to H^1. This apron runs over the rolls H^1, H^2, and the stretch-roll H^3; it is broken off in Fig. 1 near the end, in order to show the channels which are turned into H^1, for the purpose of keeping the apron extended and in its place. A leather belt H, shown full in Fig. 1, and by dotted lines in Fig. 2, runs over the back ends of the cylinder E, and of the rolls G^1, H^2, H^1, H^3, and H^4, communicating to their circumference the motion of the surface of E.

The sheets, in travelling over the threads and aprons, are unequally warped and bent, and would not form a compact pile if laid on each other in this form. They are therefore subjected to a straightening, or rather curbing, operation before being deposited.

The mechanism used for this purpose forms part of the lay-boy, and is, with the latter, mounted on cast-iron frames K, while those supporting the ruling machine proper are of wood. The sheets, after leaving the apron I at H^1, proceed on leather belts, running over pulleys L and L^1, driven by a belt L^2 from the roll H^1.

The side edges of the two sheets, on leaving the apron I, meet the curved pieces of wood M (side elevation, Fig. 2), while two belts M^1, running over the pulleys M^2 and M^3, are pressing on their middle, above the belts on the pulleys L and L^1. Their middles are thus firmly held between two belts, while their edges are raised to the top of the pieces M, and the sheets cannot fail to be thus uniformly bent. The guides M are dovetailed and fastened with keys in the wooden cross-pieces N, and may be moved sideways to suit the widths of the different sheets.

On leaving the roll L^1, the sheets drop down on the lay-boy O between the partitions O^1, which can be shifted and fastened with bolts on the wooden cross-pieces O^2. These partitions O^1 are of wood screwed on iron plates. The upright sides O^3 prevent the sheets from falling out, and are fastened on horizontal boards, tacked to the wooden cross-pieces O^2.

The sheets will not form a straight pile unless they are patted on the back edge as they come down, in the same manner as the hands of the cutter-girls pat the paper, when they receive it from the cutter and lay it on the table. The shaft of the roll L^1 is, for this purpose, provided with a crank-plate L^2, the crank-pin of which fits and moves in the thin wooden strip L^3, which is slotted out at its upper end to receive it. The lower end of L^3 is bolted to a plate on shaft L^4, and thereby connected with a flat piece of wood L^5, which is slotted out to receive two bolts, by which two strips of sheet tin L^6 are fastened to it. With every revolution of the crank-plate L^2, the top of the strip L^3 is moved sideways to and fro, and through the plate at its lower end and the shaft L^4 communicates the same motion to the strips L^6, which thus continually pat the paper as it reaches the lay-boy.

The lay-boy can be lowered by means of the hand-wheel P and racks P^1, as the

paper is piled up, but it is usually preferred to remove the paper before the piles become too large.

While the sheets travel over the cylinders B and E between the threads, and are carried by them, they are ruled on both sides. The ingenious apparatus by which this is done is represented in detail by section and side elevation in Fig. 4, Plate V, as applied to the second cylinder E.

The pens, which are the principal part of this invention, and the manner in which they are made, are shown by Fig. 3 in full size. A sheet of thin copper or brass is cut out into strips Q, at the distances and in such numbers, as the lines may be desired on the paper. They are formed as shown by Q, and, when folded or doubled up into pens, they appear in the shape of Q^1. A row of such pens is held between wooden clamps R, which are suspended on journals R^3 at their larger ends, in such a manner, that their points rest on the paper as it passes over the cylinder. A copper trough R^1, as long as the cylinder, is filled with blue ink, and into this ink is dipped a piece of flannel R^2, which rests on the clamp; R^2 sucks up the ink, and, acting as a syphon, delivers it through a number of threads which may be loose, but of the same material, or threaded from the same piece, to as many pens.

The loose, or rather, independent threads are either fastened to R^2 with a few stitches, or simply pressed on it.

If a few red lines are desired, little cups containing red ink are hung in the trough R^1, to feed the respective pens with separate threads.

The springs V, which are fastened to the frame (Fig. 2, front elevation), exercise a slight pressure on the clamps R, and through them on the pens.

After the paper has been ruled on both sides by the two sets of pens on the cylinders B and E respectively, it is sometimes desired, especially for blank books and bills, to draw lines for columns square across the other ones. But, as the head of the sheet is to be usually left free, these column lines are not allowed to extend over the whole sheet, but must stop where the bill-head begins.

This is accomplished by the following arrangement:

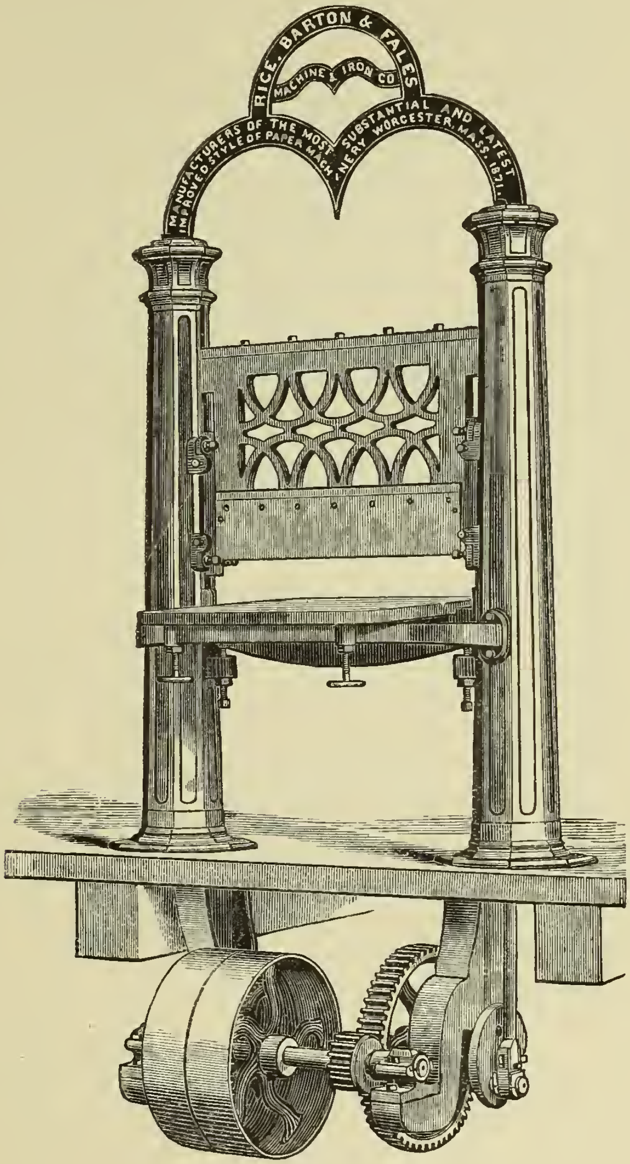
A bracket S (Fig. 4) is screwed to the upper side of the clamp R in some place where no lines are to be drawn, and which is consequently free from pens, usually in the middle. A bolt S^1 is fastened in this bracket with a set-screw, and carries at the other end a fork S^2, and a steel roll S^3 suspended in the latter. On this roll is fastened a strip of leather S^4, which is notched out at the end near the cylinder E. The whole is adjusted in such a way that the pens draw lines on the paper, while the steel roll S^3 rests on it. The paper, which has been previously ruled, is now fed to the machine, at right angle to the direction in which it travelled the first time, so that the pens will draw the column lines, and as soon as a sheet reaches the roll S^3, it strikes the notch in the leather S^4, and carries it along, thus interposing it between S^3 and the paper, raising the clamp R, and with it the pens, clear off.

When as great a length of paper as the length of strip S^4, has travelled through below S^3, the latter regains its place on the sheet, and turns until the leather S^4 has

returned to its original position, and stops its further movement. The edge of the next arriving sheet repeats the operation.

The bill-head or the space at the head of the sheet, which is free from column

Fig. 112.



lines, is exactly as wide as the distance from the notch to the end of the leather s^4, and any demand may be suited by means of a few strips of different lengths.

The sheets furnished to the ruling-machine are double ones, and must be cut on the second cylinder E by a slitter T, of the kind used on paper-machines; its shaft

rests in bearings T[1], but the steel slitter-plate runs against an iron plate instead of a second slitter-knife. The cylinder E is divided into halves by this plate, the form of which can be seen in the front elevation, Fig. 2.

The sheets must be fed in exactly the correct position, to be cut and ruled as intended, and for this purpose the angle-board X is fastened on one side of the frame. Another angle X[1], of sheet zinc, is tacked to the upright part of X, and extends with its horizontal part under the apron A. The guide-board X is slotted out, so that it, and with it the apron, can be shifted in or out to suit the width of the sheet. The sheets are fed so that one of their side-edges moves close along the guide X[1].

A great deal of note-paper is found to be ruled on three pages only, or one side of the sheet is ruled throughout, and the other only half across. This is accomplished by feeding the sheets on the apron A so, that every one covers or overlaps one-half of the preceding one. One-half only being offered to the pens of the cylinder B, the covered half must remain blank.

But, in order to line the other side all through, the sheets must offer the full surface to the pens on the cylinder E, which latter must be for this purpose speeded twice as fast as B. As soon as the sheets enter between the roll F and cylinder E, the higher speed snaps them from under their followers, and starts them separately on the balance of their journey.

189. Trimming-Knife.—The paper, having been ruled and calendered, is counted, sorted, and folded, and then trimmed.

A trimming-knife, built by Rice, Barton & Fales, in Worcester, Mass., is shown in Fig. 112.

It is moved from below the floor by a crank, which is connected with the trimming-knife by a rod inside of one of the hollow columns.

The position of the knife and table can be adjusted by screws, as seen in the cut.

190. Hydraulic and Screw Presses.—After the paper has been calendered, ruled, and folded, it is subjected for some time (not less than twelve hours or one night) to a very heavy pressure. The surface is thereby improved, and the quires become compact enough to undergo the following operations of stamping and packing, as well as of transportation, without separating into sheets.

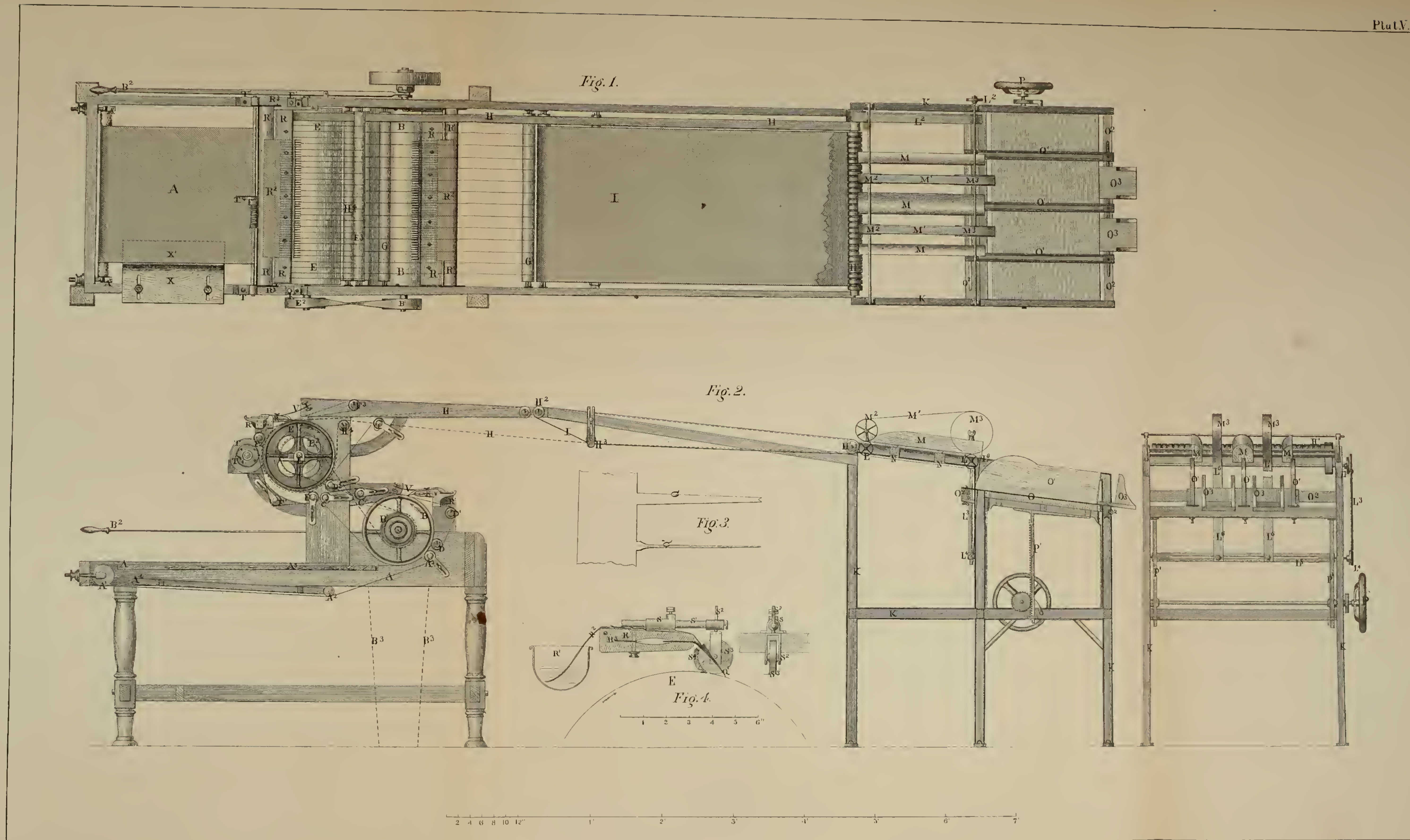
Large hydraulic presses or iron screw-presses are the only ones seen in modern mills.

A hydraulic press, as manufactured by the Holyoke Machine Company, Holyoke, Massachusetts, is represented in Figs. 113 and 114.

A press is called a hydraulic one if the power which produces the pressure is exercised through the medium of a liquid.

The objects which are to be subjected to pressure are disposed on a plate, fastened to the upper part of a plunger, which fits into a solid stationary cylinder. One or more pumps force a small stream of water through a pipe into this cylinder, displacing the plunger, which moves upward to make room for it. The distance

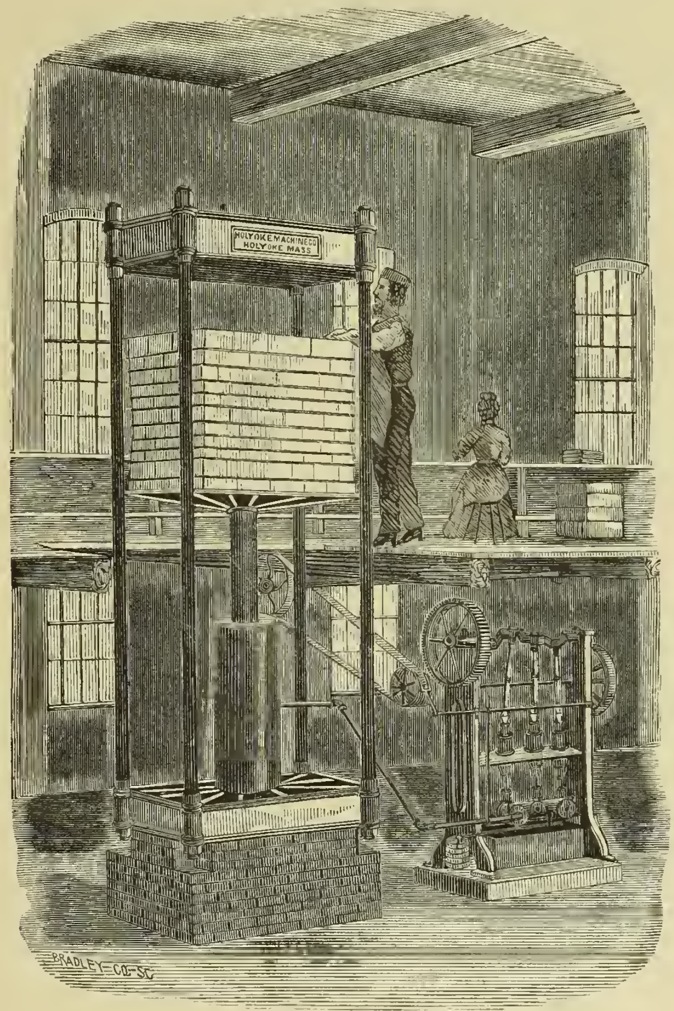
Plat.V.



between the movable and the upper stationary platform is thus constantly reduced, and the paper between them compressed.

Some skill and experience are required to put the paper on the platform in such a way that it will form a pile of equal height in every part. If not set in this manner, the paper will not present a uniform appearance, and will look worse than if not pressed at all.

Fig. 113.



The quantity of liquid which is necessary to force the plunger and platform up, is small, and the pressure exercised by it very strong (from 200 to 500 tons); the pumps may therefore work slowly, and their channels may be very small, but their bodies must be able to withstand a heavy pressure.

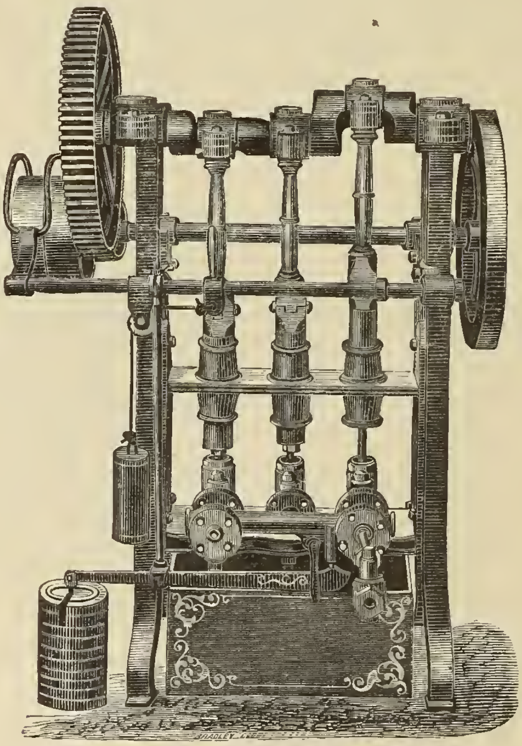
The liquid (oil) which has been forced into the press, returns to the pump as soon as a passage is opened for it, and can thus be used for many operations.

The pump, represented in Fig. 114, is driven by a belt, and stopped automati-

cally as soon as the desired pressure is obtained. The force-pipes of the three pumps empty into one common pipe, which is provided with a safety-valve. By increasing or decreasing the weight, which closes this safety-valve through the long lever, on the end of which it is suspended, any desired pressure, which the apparatus will endure, may be obtained. As soon as the pressure of the liquid against the safety-valve from inside becomes greater than that of the weight from outside, it opens, and forces the end of the lever which carries the weight upwards.

The driving-shaft, on which the pinion and fly-wheel are mounted, is also provided with tight and loose pulleys, and the fork which holds the belt in position is fastened on a horizontal rod. This belt-shifter is supported by two bearings, and

Fig. 114.



carries on its upper side a feather, which fits a corresponding excavation in the bearing nearest to the belt, and thus prevents the rod from turning. A lever, one end of which is fastened to the frame, fits a notch in this feather, and holds the belt-shifter in its place while the belt is on the tight pulley. The front end of this lever is attached to an upright rod, the lower end of which is connected with the safety-valve lever. Whenever the safety-valve opens, this rod is moved upwards, raises the lever out of the notch, and allows the shifter to move sideways.

In our drawing, the pumps are at rest and the belt is on the loose pulley; but when the apparatus is to be set in motion, the shifter must be pulled back by the

handle provided for this purpose, and the lever allowed to drop into the notch. The pumping continues until the desired pressure is reached and the shifter set free, when a weight at the end of a cord, which runs over a roll, pulls the shifter, and with it the belt, upon the loose pulley.

Modern screw-presses, as well as old-fashioned ones, are usually operated by means of long levers in the hands of men.

They are even at the present day preferred in a few mills to the more powerful and convenient hydraulic presses, because those of the latter, which happened to be used there, were not well enough constructed to give satisfaction. When the employees returned to the mill in the morning, after the pressure had been put on and the pump stopped on the previous evening, they sometimes found that the liquid had escaped and the pressure had disappeared.

Hydraulic presses must be built so that the liquid cannot find an outlet, even under prolonged heavy pressure; and if so, they are preferable to all others.

191. Stamping-Press.—The paper must frequently be stamped with monograms, names, or ornaments, and a stamping-press is therefore a part of the equipment of the finishing-room of a writing-paper mill.

The following stamping-press seems to be the favorite in the New England writing-paper mills, and is well spoken of by experienced manufacturers as a sub-

FIG. 115.

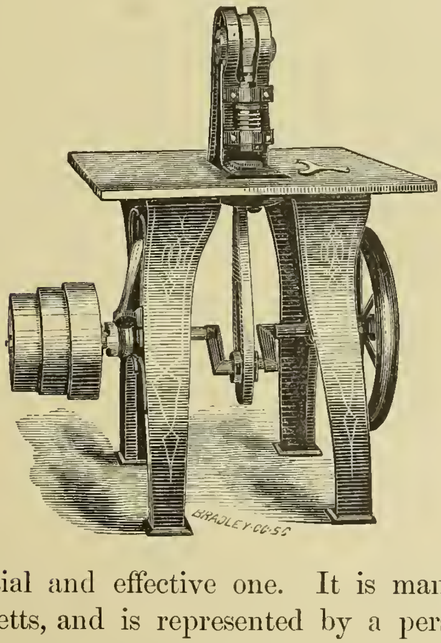
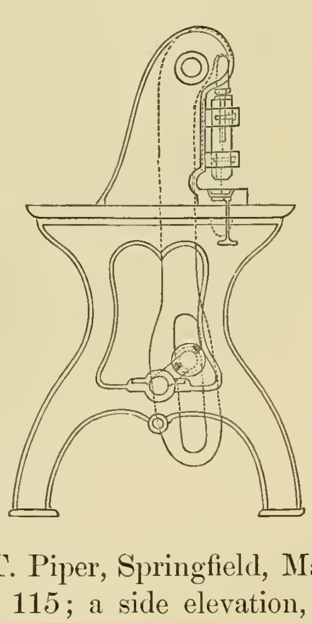


FIG. 116.

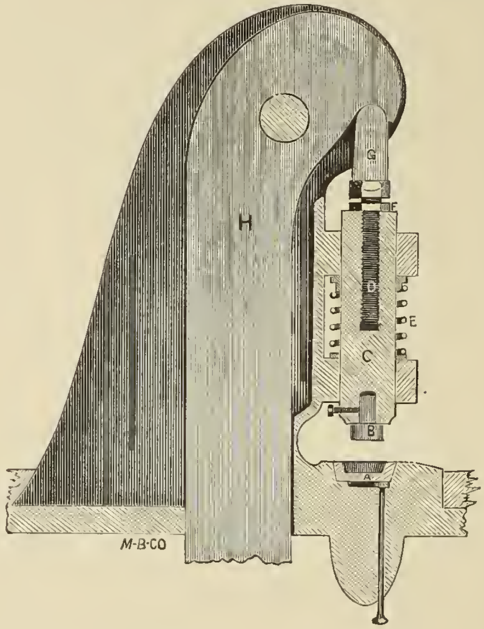


stantial and effective one. It is manufactured by E. T. Piper, Springfield, Massachusetts, and is represented by a perspective view, Fig. 115; a side elevation, Fig. 116; a section through the moving part, Fig. 117.

A in Fig. 117 is the cup which holds the bottom die; it can easily be pushed out by a rod from under the table. The steel stamp B is fastened with a set-screw in the cylinder-plunger C. This plunger is shown in its most elevated position, and

with the spiral spring E fully extended. When the plunger moves down, the upper end or collar of this spring E descends with it, the spring is compressed, and exercises a pressure upward on the plunger C. The pendulum-lever H forces the knuckle

Fig. 117.



G, and with it the stamp B, down with every revolution of the crank and driving-pulley. This knuckle G is connected with the cylinder C by the screw D; and the length of the whole plunger, including G, or the distance between the stamp and die, can be changed by turning D further in or out, and holding it in the desired position with the check-nut F.

Chapter IV.

SUBSTITUTES FOR RAGS.

SECTION I.

Historical Sketch.

192. General History and Introductory Remarks.—All things relating to the arts of writing and printing have been objects of interest and study to many of the greatest men of their times, and more than a century ago they recognized the necessity of finding materials which could to some extent take the place of rags for the manufacture of paper.

Joel Munsell, in his *Chronology of Paper and Paper-Making*, states that Jacob Christian Schaeffer, of Ratisbon (Regensburg, Germany), published, in 1765, a work in octavo, upon the different plants which he could transform into paper without the use of rags, giving specimens from a large number of materials, among which were the coton du peuplier, hornets' nests, sawdust, moss, beech, willow, aspen, mulberry, clematite, and pine, also from hop vines, the peelings of grape vines, hemp, the leaves of aloes, and lily of the valley, from arroche, moth-wort, masse d'eau, barley-straw, cabbage stumps, thistle-stalks, burdock, conferva, wheat-straw, broom corn, and Bavarian peat.

The same author also states that in 1772 there were two mills in operation in Italy for the manufacture of paper from maize or Turkish wheat; but we have no account of their success, nor that the manufacture was more than an experiment.

Christian Schaeffer also printed in 1772 a second book, of which there is a copy in the Smithsonian Institution Library, containing upwards of sixty specimens of paper, made of different materials, the result of his experiments.

The savants Seba, Réaumur, Guetard, Gleditsch, and others, had already before Dr. Schaeffer proposed substitutes for rags.

At present, when paper and paper-making have become, through more universal education, matters of importance to everybody, men, from almost all walks of life, consider it their vocation to discover new substitutes and methods of working them. They have never studied paper-making, are not aware that thousands of the best brains have been racked, and that hardly a plant exists which has not been tried or proposed for this purpose. We observe therefore the strange phenomena that now

and then substances are proposed, and patents taken out, for new processes of making paper, which have perhaps been tried and condemned many years ago.

Every earnest contributor to the progress of our art is heartily welcome, but, guided by science, the manufacture has already reached such a degree of perfection that any real improvement can only be made by those who have, by careful study, acquainted themselves with all the progressive experiments and practical trials, which have been the means of bringing it to its present high position.

193. Matthias Koops.—The foregoing remarks occurred to us while perusing a book, which by good fortune and purchase found its way into our hands.

It was printed in the year 1801 at London, and written by Matthias Koops, Esq. It is entitled, "Historical Account of the Substances which have been used to describe Events and to convey Ideas, from the Earliest Date to the Invention of Paper. Second Edition."

It begins with the following address to King George the Third:

"Most Gracious Sovereign.

"Sire: Your Majesty having been most graciously pleased to grant me patents for extracting printing and written ink from waste paper by reducing it to a pulp, and converting it into *white paper*, fit for writing, printing, and for other purposes; and also for manufacturing paper from straw, hay, thistles, waste, and refuse of hemp and flax, and different kinds of wood and bark, fit for printing, and almost all other purposes for which paper is used.

"And Your Majesty having, in September last year, condescended to permit me to lay at your feet the first useful paper which has ever been made from straw alone, without any addition of rags; the gracious reception it has met with from Your Majesty, the approbation of the public, and the encouragement which the legislature has given me by passing an Act of Parliament in its favor, has engaged me to reprint these lines on paper manufactured from straw solely in a more improved state, although not yet brought to such a state of perfection as it will be made in a regular manufacture, which must be entirely constructed for such purpose, and which I most humbly flatter myself will now much sooner be established by the indulgence which your Majesty's Parliament has granted me. This new essay proves there cannot be any doubt that good and useful paper can be made from straw alone.

"The favorable manner in which Your Majesty has deigned to look on these, my humble attempts of discovery, shall be a constant incitement to future exertions, and the prospect of meriting commendation of a king, always ready to countenance the most humble endeavors which tend to the common welfare, and who has proved himself the illustrious patron and protector of arts and sciences, obliges me to unremitted perseverance to bring my attempts to perfection in the prospect of meriting Your Majesty's commendation, which will be the greatest pleasure I can be sensible of.

"With the most ardent wishes for your Majesty's health and longevity, and with all possible deference and humility, I beg leave, Most Gracious Sovereign, to subscribe myself,

"Your Majesty's most devoted, most obedient,
and most humble servant,
"Matthias Koops.

"17 James Street, Buckingham Gate,
"August 30th, 1801."

We read on page 250 to 253:

"I have had the satisfaction to witness the establishment of an extensive paper-manufactory since the first of May, 1800, at the Neckinger Mill, Bermondsey, where my invention of remanufacturing paper is carried on with great success, and where there are already more than 700 reams weekly manu-

factured, of perfectly clean and white paper, made without any addition of rags, from old waste, written, and printed paper, by which the public has already been benefited so far that the price of paper has not risen otherwise than by the additional duty thereupon and the increased price of labor. And it will not be many weeks before double that quantity will be manufactured at the said mill.

"Thus far succeeding, my other more extended views, in assiduously endeavoring to manufacture the most perfect paper from straw, wood, and other vegetables, have been likewise successful. And I am able to produce to the public very strong and fine paper made thereof, without any addition of other known paper-stuff, notwithstanding I have not yet had the advantage of making it in a mill regularly built for such a new undertaking. The paper whereupon this is printed is an undeniable proof. It is, however, only of an inferior quality, being made from the straw in the state it comes from the farm-yard, without assorting the weeds and those parts of the straw which have been colored by the weather. I have used this kind of paper on purpose to demonstrate the progress of so singular an undertaking, and to prove its possibility to the world, notwithstanding the opinion of many scientific men, particularly that of the ingenious Breitkopf at Leipsic, that paper made from straw cannot be used for printing. This specimen, and others of a much finer quality which have been manufactured, leave no doubt that, when the manufactory has been regularly established with the necessary implements, I shall make straw paper in as great perfection as any made from rags, and by several trials which I have made to change the yellow color into cream color and white, it seems to be unquestionably practicable, which will extend its consumption, and remove the prejudices which are generally cherished against new discoveries, notwithstanding its natural color is not only pleasing, but grateful to the eye for writing and printing, principally for music notes by candlelight. Copper-plate printers assert that it takes the impression superior to French copper-plate paper, and it has a beautiful effect in landscapes and pictures, for drawing and paper-hangings."

On the title-page is found the following sentence:

"Printed on paper re-made from old printed and written paper."

And in several other places it is said that part of the edition is printed on straw paper.

The paper of the copy in our possession is even now, after seventy years, perfectly white and OF GOOD QUALITY.

The straw paper, on which a portion of the edition is printed, is strong and tough, but of a light-brown color, similar to straw wrapping-paper, on which, however, the printed matter can easily be read.

The last fifteen pages of the book are printed on paper made entirely of wood; it has the color of light Manilla, and is rather rough.

The wood has evidently not been thoroughly reduced to pure fibres, but nevertheless the paper is strong and tough, and the printing shows well upon it.

The first part of the Appendix is interesting, because it shows how well its author discerned the future development of the art. It reads as follows:

"As an Appendix to this little tract, I think it proper to submit a few more remarks on the national importance of discovering materials which can be converted into paper, and grow sufficiently abundant in Great Britain, without the necessity of importing them from foreign countries.

"The following lines are printed upon paper made from wood alone, the produce of this country, without any intermixture of rags, waste paper, bark, straw, or any other vegetable substance, from which paper might be, or has hitherto been manufactured; and of this the most ample testimony can be given if necessary.

"Having thus far succeeded in my researches to make an useful paper from one kind of wood, I

doubt not but that I shall find many others equally eligible for the same purpose, of which I trust it will be in my power, within a few weeks, to give indisputable proof that my expectations have been well founded, and that I have not cherished a visionary opinion.

"History furnishes us with numerous examples of one discovery giving birth to others, and if my success of having increased the quantity of paper materials, by rendering these applicable to that which have never been before applied to such a purpose, should incite active and industrious artists to make farther improvements in their various manufactures, my feelings will be amply gratified. Various hints may be suggested to those who are already acquainted with the properties of paper, when passed in lamina on each other; it may, by this means, be made to form a substance as durable and more impenetrable than oak.

"Having long admired the celebrated manufacture of Mr. Clay at Birmingham, who has demonstrated to what perfection and beauty it has been brought, it will, in the course of time, perhaps not be surprising to find that objects of greater consequence will engage their attention in the same pursuit, and prove that the properties from successive layers of paper may be found a substitute for many purposes for which at present foreign wood is required.

"One of the greatest obstacles to the improvement and extension of this art has been probably the scarcity of the raw materials. Now that these are found *at home* in sufficient abundance, means may be found to supply manufacturers with any quantity required, at reduced prices.

"It may probably be ultimately proved that paper thus prepared will be a lighter, neater, and more durable covering for buildings of all kinds, and it is equally true that the ingredients with which the cement can be composed will render this substance not only incombustible, but more durable than slates, tiles (which in the course of time become brittle), and wood in its natural state, and incorruptible by insects. Who can say that coach-makers, chair-makers, and cabinet-makers will not make use of it for carriages, chairs, and elegant household furniture, and reflect that a substance possessing such superior properties ought to be preferred, having flexibility, hardness, and capability of being worked with infinite greater neatness and lustre than wood, which is so much affected by the air and weather. Converting wood, straw, and other vegetable substances into paper may therefore be rendered useful for a variety of purposes; and the substance of the wood paper, on which these lines are printed (which is the first attempt to make it in a quantity), exhibits an indisputable proof that useful paper may be manufactured from the hardest part of wood alone, destitute of its pith or bark, and, if any of the suggestions here stated, as to the application of the manufactured material, should be thought reasonable, experiments of some able manufacturers will prove that this paper can be again converted into a substance, more hard and durable than any wood of natural growth."

194. The Principal Substitutes of the Present Time.—The efforts of Jacob Christian Schaeffer, Matthias Koops, and others, have been improved upon, so that waste paper, straw, wood, esparto, cane, and several other vegetable substances of less importance, are at present used in large quantities for the manufacture of paper.

We shall treat of these substitutes in the following order:

Section II. Fibres or cellulose.—This Section does not treat of any particular raw material, but of the elementary substance which forms the body of all our paper.

Section III. Waste paper.
Section IV. Straw.
Section V. Esparto.
Section VI. Wood.
Section VII. Mechanically prepared wood-pulp.
Section VIII. Cane.—Jute and Manilla.

SECTION II.

Fibres or Cellulose.

195. Chemical Composition and Formation.—The body of every plant consists principally of infinitely small tubes or cylinders, called cells. Their forms and combinations are of endless variety, but they always contain, chemically, the same proportions of carbon (C), hydrogen (H), and oxygen (O). Their substance is called cellulose ($C_{12}H_{10}O_{10}$), and, when pure, is a white, slightly transparent body, of a brilliant appearance, like silk, without either smell or taste, of a specific gravity of 1.52. It is composed of—

12 atoms of	carbon (atomic weight 6),	72, or	44.45	per cent.
10 "	hydrogen (atomic weight 1),	10, "	6.17	"
10 "	oxygen (atomic weight 8),	80, "	49.39	"
		162, or	100.01	"

This composition is confirmed by the proportions of the atoms contained in the wood of a number of trees.

Chevaudier has found them, for—

	Beech.	Oak.	Birch.	Aspen.	Willow.
Carbon (C),	49.89	50.64	50.61	50.31	51.75
Hydrogen (H),	6.07	6.03	6.23	6.32	6.19
Oxygen (O),	43.11	42.04	42.04	42.39	41.08
Nitrogen (N),	0.93	1.29	1.12	0.98	0.98

These analytic results show that the atomic composition of trees or wood is very nearly like that of pure cellulose, and it must be concluded that wood consists almost altogether of cellulose and of substances which are isomeric with it.

Tunicsin, starch, dextrin, gum, and several other substances, are isomeric with cellulose; that is, they are composed of the same proportions of carbon, hydrogen, and oxygen, but their atoms are differently grouped, and make up bodies widely different in qualities and appearance. (The most generally known examples of isomeric bodies are the formations of pure carbon: diamond, plumbago, and charcoal.)

The reduction of vegetable matters to fibres is more readily understood by a contemplation of the work of nature in building up and decomposing them.

The animal and vegetable worlds work for each other; all animals inhale, and every burning fire consumes oxygen (O); they load it with carbon, and return it to the

atmosphere as carbonic acid (CO_2). The green parts of all plants absorb this carbonic acid, decompose it again into its elements, retaining the carbon and exhaling the oxygen. Carbon, which has been extracted from the food of animals, is presented to the oxygen in the lungs through the medium of the blood, transformed into carbonic acid, and thus returned to the plants for the formation of new food.

The elements of carbonic acid, carbon and hydrogen, and those of water, hydrogen and oxygen, meet in plants, and are so grouped by the action of the latter, that they furnish a liquid substance or sap, which descends into the stem and solidifies into cells or cellulose in proportion as it loses its oxygen. The principal component of this sap is glucose (grape-sugar), consisting of—

$$\underset{\text{Carbon.}}{6C} + \underset{\text{Hydrogen.}}{5H} + \underset{\text{Oxygen.}}{5O} + \underset{\text{Water.}}{HO}$$

which, having once been formed in the leaves of a tree, is forwarded to the centre, and transformed into cellulose, creating the rings, which indicate by their number as many years' growth.

The roots take up the mineral substances, and the bark consists of the impurities which are thrown out by the forming wood.

The changes of glucose into cellulose may be explained as follows:

Cellulose being put at $24C + 20H + 20O$ + water,

1 atom of glucose is represented by	$6C + 5H + 5O$ + water (HO).
2 atoms of glucose give	$12C + 10H + 10O + HO$, or dextrin.
1 atom of glucose and 1 of dextrin give	$18C + 15H + 15O + HO$, or starch.
1 atom of glucose and 1 of starch give	$24C + 20H + 20O + HO$, or cellulose.
1 atom of glucose and 1 of cellulose give	$30C + 25H + 25O + HO$, or bicellulose.

and so on; every additional atom of glucose producing a higher concentration of cellulose or tenser and harder wood, such as tri, quarto, &c.,—cellulose.

All of the compounds of oxygen, hydrogen, and carbon are the more soluble, as they contain more oxygen (O), and form into solid bodies as they lose it. To dissolve them, nature just reverses the process of their formation; it adds oxygen, and decomposes them again into carbonic acid and water.

Ulmic acid is produced in decaying plants by slow oxidation, and assists in the solution of the intercellulose or substances surrounding the fibres. This is done at the ordinary temperature, and with only an insignificant amount of alkali; while we require a high temperature and large amounts of alkali to do the same thing artificially, but in a short time.

Nature seems to indicate hereby that not only temperature and alkali are to be considered in the preparation of vegetable fibre for paper, but that time also is to play a very important part, and that either of the former or both may be reduced if the latter can be sufficiently increased to make up for that reduction.

It is in all cases very difficult to find the point at which all the substances which surround the fibres are dissolved, while the fibres may yet remain uninjured.

Flax, hemp, and cotton rags consist of pure fibres only, with the addition of fat, color, gluten, and impurities; but the substitutes, which are used in their original form, contain incrusting, glutinous, resinous, and silicious matters, amounting sometimes to one-half or more of their weight, which must be eliminated if the pure fibres be required. The same agents which dissolve them will also destroy the fibres if time and opportunity be given; but fortunately the cellulose resists their influence much longer than any other part, and, guided by experience, it is possible to regulate the operations so that the larger part of the fibres can be obtained in a pure state.

196. Mechanical Formation and Appearance.—Microscopic examination shows that the fibres of various plants are differently formed.

The single flax fibre consists of one long, thin, cylindrical cell of about $\frac{1}{2500}$ inch diameter, with a very fine channel all through it, and is very tough and elastic. The action of the beating-engine has for its object to crush in the sides of these cylinders, so as to render them in every direction more flexible; and they produce a very strong paper, even if the fibres have been cut up into short pieces by the operation. Hemp has a similar fibre, only stronger, thicker, and with a wider channel.

Cotton has a long fibre, which becomes flat while drying, and twists upon its axis. This twist makes it bulkier, and is the cause of its forming a rather spongy paper.

Straw yields a rather stiff, nearly round, tubular fibre, with pointed ends, about $\frac{1}{11}$ of one inch in length.

The fibres of the evergreen coniferous woods, such as yellow and white pine, hemlock, &c., somewhat resemble cotton; they are dotted, long, flat, tape-like, bend easily in one plane only, and are, especially yellow pine, of considerable length.

The deciduous woods, such as poplar, hickory, ash, cherry, &c., yield a fibre averaging about $\frac{1}{10}$ of one inch in length and somewhat over $\frac{1}{1000}$ inch diameter, tubular, with pointed ends, and, if perfectly free from incrust or resinous matters, very flexible and with but little elasticity; but if coated with intercellular matter, they become very stiff, and are apt to break when forcibly bent.

Some of the woods have longer fibres, but cannot produce so good a paper as flax or hemp, because they have less inherent strength and flexibility.

The comparative strength of papers made of a certain kind of raw material depends to a large extent on the length of the fibres obtained from it. But in comparing the value of different materials, the inherent qualities of their fibres seem to be of more importance. The cells of which they are composed should be flexible, so that they can intertwine and felt themselves easily. The cell-walls of some of our best fibres are not bare inside, but clothed all over with projecting parts, filling the cylinders with an elastic mass, which acts like a spiral spring and prevents the walls from breaking, when they are bent.

The incrusting matter, if not thoroughly removed, thickens the walls of the

fibre-tubes, or binds several of them together. These thickened fibres or fibre-bundles have little flexibility, and partake more of the stiff and unwieldy nature of straw or wood.

We add here, from William Allen Miller's *Elements of Chemistry*, London, 1869, the following description of the mechanical and chemical formation of the cellulose, or, as he prefers to call it, *cellulin:*

"If a thin slice of wood be examined under the microscope, it is immediately apparent that it is not a homogeneous structure, but that it is composed of a cellular or fibrous substance, the texture of which assumes a different appearance, according as the slice has been cut across the grain of the wood or parallel to it. This ligneous fibre, or true woody matter, consists, according to the researches of Payen, of two essentially distinct portions. One of these has received the name of *cellulose;* it constitutes the basement-tissue found in all vegetables; it occurs nearly pure in cotton, linen, elder pith, and in the pith of the Aralia papyrifera, from which *rice-paper* is prepared. The other portion is a deposit of incrusting matter, which lines the interior of these cellules in amorphous layers, varying in thickness according to the age or character of the ligneous substance.

"Cellular tissue forms the groundwork of every plant, and, when obtained in its pure state, its composition is the same, whatever may have been the nature of the plant which furnished it, though it may vary greatly in appearance and physical characters. For instance, it is loose and spongy in the succulent shoots of germinating seeds, and in the roots of plants, such as the turnip and potato; it is porous and elastic in the pith of the rush and the elder; it is flexible and tenacious in the fibres of hemp and flax; it is compact in the branches and wood of growing trees, and it becomes very hard and dense in the shells of the filbert, the peach, the cocoanut, and the *Phytelephas* or vegetable ivory. Vegetable cellular tissue in its succulent form is easily digestible, but, when it has become compact and incrusted with true woody matter, as in the husks of the seed and in the hard portions of the stems, and even when simply condensed into tenacious fibres, like those of hemp and flax, it is no longer digestible, or in a condition to serve as nutriment to the higher orders of animals."

From the foregoing, it follows: that plants are in the same proportion more unfit to be used for the manufacture of paper, as they are more valuable as food for animals.

"It is scarcely possible to obtain cellulose free from ligneous tissue by artificial means, since the incrusting, woody matter, when once deposited within its meshes, is retained with great obstinacy, but it is presented in a pure condition in finely-carded cotton, in linen, and in the finest kinds of filtering-paper. To these sources the chemist usually has recourse when he desires to examine the properties of cellulin.

"Pure cellulin is a white tasteless substance, insoluble in water, alcohol, ether, or oils. It is heavier than water; its fibres are transparent, and exert a depolarizing influence upon a ray of polarized light. A solution of well-washed, freshly-precipitated, hydrated cupric oxide, or cupric carbonate, in dilute ammonia, dissolves the fibre in most of its forms, though in some cases, as in that of the *rice-paper*, this solution does not take place until the vegetable fibre has been boiled with diluted acids. Cellulin is precipitated from the cupric solution, unaltered in composition, on acidulating the solution with an acid. Cold, concentrated sulphuric acid dissolves it, and produces a treacly-looking liquid, converting it after dilution and boiling, first into dextrin, and subsequently into grape sugar. Weak acids exert but little effect on cellulin, but the action of these and of all other solvents is materially greater upon the recently-formed cellules than upon the old ones. By prolonged boiling with dilute sulphuric acid, the less compact forms of cellulin are gradually converted into glucose. Hydrochloric acid in its con-

centrated form dissolves cellulin, and deposits it on immediate dilution with water; but if it be left undiluted for two or three days, no precipitate occurs on the addition of water. Alkaline liquids, when dilute, do not act upon cellulin, but when concentrated they gradually destroy its texture. According to Péligot, if cellulin be moistened with water and submitted to distillation with an equal weight of solid, caustic potash, wood spirit distils over, and potassic oxalate is formed in the residue. A solution of chlorine acts but very slowly upon cellulin."

The same author says in a subsequent article on *Paper-making:*

"An excess of chlorine must be carefully avoided, because it is liable to enter into chemical combination with the fibre, and, by displacing a portion of the hydrogen, to form a substitution compound, which, being destitute of tenacity, furnishes a brittle paper."

197. Conclusions.—The usefulness of a plant for the purpose of making white paper depends upon the nature of its fibres, upon the proportion of cellulose contained in it, and upon the expense at which this can be freed from the incrusting matters or intercellulose.

Many coarse papers, such as wrapping, or boards, permit of the use of fibrous plants in the original state, even if they contain only a small proportion of fibres. Some kinds of swamp-grass, for instance, which could not profitably be transformed into white paper, are extensively used for this class. Their component parts, other than cellulose, which would have to be eliminated for the manufacture of white paper, enter into the body of the wrappers or boards.

SECTION III.

Waste-Paper.

198. Trade and General Assortment.—Waste-paper, the shoddy of the paper-manufacturer, is next in importance to rags, as it is already prepared pulp, the surface of which only requires cleaning. The supply of this material increases in the same proportion as that of paper generally; it should and will be saved in every household as well as rags.

In this country and in England, where the price is high enough to offer inducements for its preservation, enormous quantities are gathered and worked up.

We have already shown that this material was remanufactured by Matthias Koops, over seventy years ago, and yet it has only within the last twenty years been appreciated to any extent and generally used.

Wrapping-paper, made of straw and other cheap materials, and paper bags have taken the place of old books and newspapers in the stores, for the purpose of packing up goods, and the increasing demand has caused old paper to be saved, where it would formerly have been considered useful only to kindle a fire.

Waste-paper is sorted like rags into a good many qualities.

The cuttings of new white paper make up the highest class, and are called *white shavings;* they are subdivided into hard or sized and soft or unsized shavings.

Colored shavings are the cuttings of colored paper.

Paper without printer's ink, but only writing fluid on its surface, such as old blank-books and letters, is highly valued, but found only in comparatively small quantities,—another evidence of the daily increasing importance of the printing press.

Printed papers are divided into three classes:

The first one contains the best qualities of clean printed papers, such as books deprived of their covers and backs, letters, blank-books, and others, which may be partially printed upon. It is called *No.* 1 *imperfections.*

The second class consists of clean newspapers, pamphlets, and other waste of white printed paper. It is called *No.* 2 *imperfections, or No.* 1 *prints.*

Soiled printed or writing papers, which have once been white, make up the third class, or *No.* 2 *prints.*

Manilla papers, board cuttings, wrapping papers, and any other kind of which enough can be gathered, are put up separately, and form as many different grades.

The subdivisions, according to quality and cleanness of the stock, are nearly as numerous as those for rags.

Waste paper is shipped like rags in bales, which weigh from 300 to 800 pounds, and there are as many tricks practiced in this trade as in the sale of rags.

Sometimes we find the best stock on the outside, and a very poor lot in the centre of the bale, or the papers may be moist from the addition of water. As the bales are mostly sold by their gross weight, they are sometimes covered with a large quantity of cheap, heavy bagging.

Experience only, can teach how and where to buy.

199. Dusting and Sorting.—The treatment of old paper in the mill is very similar to that of rags, but, while the latter can be reduced to their single component fibres only by the use of much power, old paper is already prepared pulp, which has only to be cleaned on the surface, and washed and brushed in the engine, to be ready for the machine.

Old papers are always more or less mixed with rags, twine, or threads, which would require severe beating to be transformed into pulp. But as they can only receive a slight brushing in company with the papers, they appear in the finished pulp in nearly their original form, and are a source of constant trouble.

Everything which has not once been white pulp must be carefully sorted out, especially yellow straw, or dark wrapping-paper. Dealers never sort so carefully that some of these may not find their way into the bales, and if allowed to become mixed with the pulp, they will be ground up, and appear in the finished paper as numerous yellow, gray, or colored spots.

Many sheets, especially in the prints, are folded or bundled up into rolls, in which pens, dirt, or seeds of some fruit, may often be found. All waste-paper, even of the best qualities, sticks closely together, and must be opened and separated into distinct pieces; nothing does this more effectually than a rag devil or a railroad-duster; it knocks the papers apart, and all the heavy, small impurities fall through the wire or grate.

The first thing to be done with waste-paper, when taken from a bale, is therefore to run it through a devil and duster. If this is well done, the papers will reach the sorters, opened out into single sheets, free from dust and all small impurities, and torn into convenient sizes. They can be assorted more thoroughly and in a shorter time, and, being free from dust, are less objectionable than the stock taken directly from the bales.

A railroad-duster, of the kind represented by Figs. 12 and 13, connected by an apron, with an open cylinder-duster, of the kinds shown in Figs. 9 and 10, or 11, are frequently used; the first opens the papers, and the second gives them time to throw off the impurities. In mills, where these papers constitute the only raw material for the manufacture of better grades, such as book paper, as many as three of these dusting-machines are sometimes used in connection.

The sorting-rooms for waste-paper have the same general appearance as those for rags, with the difference that no knives are used, as no cutting is required.

Some mills, which use waste-paper exclusively, sort it into at least the following grades:

White No. 1 shavings.
White No. 2 shavings.
Colored shavings.
White letters.
Blue letters.
Book paper.
No. 1 prints, consisting principally of clean newspapers.
No. 2 prints, consisting principally of soiled newspapers.
Colored papers.
Boards and wrapping paper.

All these papers, except the last class, are subsequently boiled with soda, and it has been observed that many newspapers and lower grades of books or pamphlets, which seem to be made of esparto, or some kind of wood, turn yellow-brown under its influence. The presence of such papers injures the color in spite of all bleaching, and it is therefore necessary that they should be sorted out, and worked into lower grades of paper.

It requires much experience to judge from their appearance, which papers are made of esparto or wood, and sometimes it is altogether impossible. A basin, with a strong solution of soda, is therefore kept in the sorting-room, and whenever there is any doubt as to the composition of a piece of paper, it is simply dipped into the basin. If the soda turns it yellow or brown, it belongs to No. 2, but if it has no effect on the color, it goes into No. 1.

After this experiment has been often tried, the sorters will be able to recognize the nature of the raw material of which the paper has been made, more precisely, and have recourse to the test only in exceptional cases.

One experienced woman can sort 500 to 1000 pounds of the ordinary class of prints or imperfections per day.

200. **Boiling.**—The extraction of ink and fat by boiling is the next operation.

Writing ink can be extracted with water alone, but a solution of soda is required for printing ink.

If a rotary is used for this purpose, the operation is carried on exactly as with rags, but instead of lime, a solution of soda, or better, of caustic soda, is added to the papers.

The motion of the rotary boiler, slow as it may be, causes friction, and, aided by the liquid and heat, reduces a portion of the papers to pulp.

The fibres of this pulp are in the most reduced state or division, and the steam, in blowing off, cannot fail to, and does carry off some of them mechanically. While the papers are washed, another and larger portion of these fine fibres escapes with the wash-water.

The solution of soda destroys the printing ink by dissolving its fat, but it also assumes the color of the ink, and turns more or less black itself. The pulp and soft-

ened papers become thoroughly impregnated with this black liquor, and can only be cleaned by the most persistent washing.

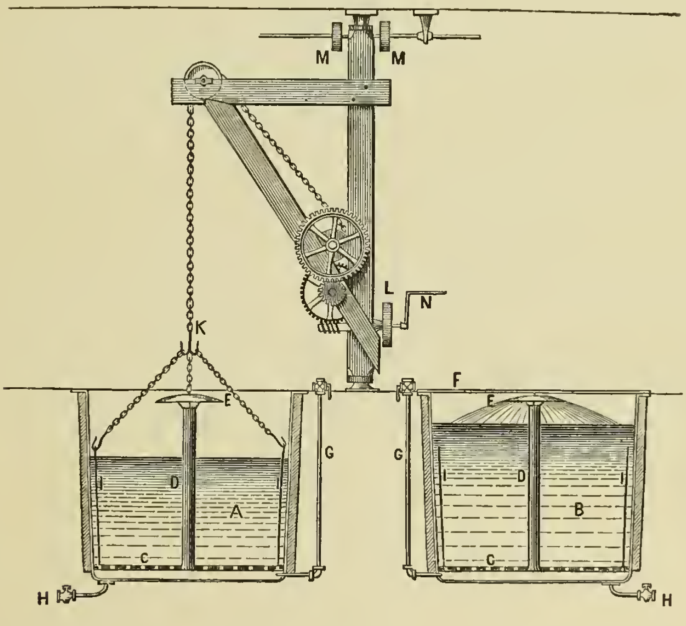
It is evidently preferable that the papers should not be in motion while they are boiled, so that they will not be turned into pulp before the proper time. It will also be easier to wash papers which have not been stained all through with black liquor, and the inevitable loss of fibres, which fine pulp must sustain, is avoided.

Waste paper is therefore boiled in stationary tubs in nearly all the mills which make its remanufacture a specialty. It is true that tubs consume more steam than rotaries, because they cannot be closed steam-tight, but this loss is more than compensated for by the advantages gained.

We find them in many mills constructed of wood, with wooden perforated false bottom and cover. The wood is soon destroyed by the soda; it peels off in flakes and pieces, and not only requires frequent renewals, but becomes mixed with the pulp, and thus injures the paper. It is therefore cheaper and better to make the tubs of iron.

Fig. 118 represents an arrangement of boiling-tubs in connection with a hoisting apparatus, as used in some of our most successful mills.

FIG. 118.



The tubs A and B are of light boiler iron, 8 feet deep, of 8 feet diameter at the bottom, and $8\frac{1}{2}$ feet at the top, covered with a mantle of wood, which prevents the escape of heat. The false bottoms C are perforated all over, and carry in the centre upright pipes D, overtopped by bonnets E. The steam enters from the pipe G into a coil (not shown in Fig. 118) below the false bottom, from which it is evenly spread through all parts of the tub by means of a large number of small holes.

The liquid can be drawn off through the pipe and valve H. A flat iron cover F, in one or two pieces, is laid over the top.

To begin the operation, the tub is filled to $\frac{1}{4}$ or $\frac{1}{3}$ with a solution of soda; steam is started on, and the whole mass brought to the boiling-point before any paper is put in. The boiling liquid rises up through the pipe D, and, striking against the bonnet E, is spread over the whole surface of the tub. As soon as this takes place, the papers are gradually thrown in, so that all will be soaked before they reach their resting-place.

We have often seen waste-papers imperfectly boiled, because they were packed into the tub in a dry state, and the solution added afterwards. When the operation was finished, it appeared that some portions of the stock had not been reached by the liquid; that they had not even been wet, simply because they had been packed together so tightly that the solution could not penetrate them. It is therefore of importance that the papers should become thoroughly soaked while they are being put in; and if this is done, as much paper may be tramped into the tub as it will hold.

The liquor circulates easily through a mass of wet paper, but dry paper, if packed into a solid body, seems to be nearly impervious to it.

The tubs of our section Fig. 118 (8 by 8 feet) hold about 4000 pounds of papers each, while one of 10 feet diameter by 10 feet depth would have a capacity of nearly 8000 pounds of imperfections. Heavy book papers require less room than news or shavings, and the quantity which a tub may hold varies accordingly.

The papers must be packed all round as uniformly as possible, because the boiling solution may otherwise find an easy channel downward in some part, and leave other portions untouched.

The liquid which boils up through pipe D, should be spread over the whole surface as uniformly as possible, and an iron bonnet E, previously described, is sometimes used for this purpose, but often the cover F itself is used in its place, by making the pipe D long enough to come up close to it.

A uniform percolation of the liquid through the mass can be easier obtained in tubs of moderate diameter than in very large ones.

The necessity of emptying the tubs by hand used to be in many mills one of the principal objections against their use, but the boiled mass is at present hoisted out by means of cranes.

An arrangement of this kind is represented in Fig. 118. The false bottom C is made of perforated, wrought or cast-iron plates, fastened to a strong frame of iron bars, and can be lifted out by means of three or four iron rods I. When the boiling operation is finished, the hooks K are lowered and connected by short chains with the rings or hooks at the upper ends of the rods I.

The pulley L of the crane is then connected by a belt with the driving-pulley M, or the crank N is turned by hand, until the whole mass appears above the floor, when the crane is moved around on its pivot, to a place where the false bottom C can be deposited. Another spare false bottom may at once be attached to the hooks K, lowered into the tub, and a new operation started.

The papers come out as a solid mass, looking like a very large cheese; they are easily hoisted, without rubbing, in ascending, against the sides of the tub, because of its conical form or constant enlargement towards the top.

The original weight of the papers is increased by the liquid absorbed by them; they represent a very heavy mass, and can only be moved slowly. The crane in Fig. 118 is provided with double gears and a worm-wheel, driven by one of the two pulleys M, according to its location. The tubs are located in a circle around the crane, but may be disposed in any other manner, with hoisting-apparatus of any desired construction.

The time of an operation, from emptying to emptying, varies from fifteen to twenty-four hours. If several tubs are used, steam should be admitted to them by turns, or to only one at a time, in order to make its consumption more regular.

The escape steam of a steam-engine can be used with great advantage to boil these papers. It must enter the tub under the false bottom, in at least two or three places, to be divided evenly all round.

Some paper-mills work up enormous quantities of waste paper, which are boiled exclusively with escape steam.

201. Preparation and Use of the Soda Solution.—The soda is universally used in the form of soda ash, and some paper-makers simply sprinkle it in the dry state through the papers. By so doing, they introduce all the dirt and insoluble matter, contained in the soda ash, into the pulp. What this amounts to, can easily be seen by dissolving one lot in hot water, and screening it through a fine wire-cloth.

If as much dirt as the soda solution leaves on the wire were thrown into the engines, the manufacturer would probably consider the pulp ruined; but he hesitates not to add it in the form of soda ash. If previous dissolution and screening are considered too laborious, the soda can be tied up in a coarse bag, and laid on the bottom of the tub before it is filled with papers. The impurities remain in the bag, and can be removed with it when the operation is finished.

The soda dissolves the printing ink, but as the papers are not exposed to friction or motion, the dissolved ink remains on the surface of the sheets, and is not diffused all through the liquid.

A part of the solution is absorbed by the papers, and leaves the tub with them, but the remainder is in a comparatively pure state, and can be used again.

Many paper-makers do not draw off the liquor, but only hoist the papers out, add a fresh solution to the liquid, which remains in the tub, and begin a new operation. This can be continued for many weeks until the solution begins to acquire a dark color, when it must be discharged.

In some mills the liquor is drawn off through the outlet-pipe H, into a lower receiver, as soon as the boiling is finished. Before entering this receiver, it passes, however, through a wire-cloth, which retains the impurities, and it is subsequently returned to the tub by means of a pump, to serve with an addition of fresh solution for the next operation. The mass of boiled papers being much lighter after the liquid

has been drained from it, can therefore be hoisted up with less power, and the screen retains pieces of paper and impurities, which will accumulate below the false bottom, if the liquid is not drawn off for a long time.

Some manufacturers prefer the latter plan, for the reasons mentioned, to the simpler first one.

The liquor which is used for boiling by the majority of manufacturers, consists simply of a solution of soda ash, the purest and most caustic soda ash being generally preferred for this purpose. In some paper-mills its causticity is increased by boiling with caustic lime, and a few paper-makers make the solution thoroughly caustic.

The principal object of the boiling operation is to transform the fat of the printing ink into a soluble soap. The soap-maker does precisely the same thing, but he uses caustic soda (NaO) only. So-called caustic soda ash contains seldom more than from 10 to 20 per cent. of its soda in the caustic state, while the balance is carbonate of soda (NaO,CO_2).

The elimination of the carbonic acid can only be beneficial, and we would therefore suggest that the soda solution should always be made caustic. It should be boiled with its due proportion of caustic or burnt lime, and the clear liquid drawn off into the tub.

For particulars we refer to Section IV, on Straw-Paper.

The manufacturers who are most successful in this specialty use quantities of fresh soda ash, varying from 10 to 20 pounds per hundred of the weight of papers in addition to the solution which has been left from the preceding operation.

Waste-paper requires more soda, in proportion as it is more thickly covered with printing ink.

202. Washing and Bleaching.—The boiled papers are gradually removed from the false bottom on which they rest in the form of a large cake, and furnished to the washing-engine.

These engines should be provided with blunt knives and clear wash-water, and their revolving washers must be kept at work until the water runs off clear, when the papers may be brushed out by lowering the roll.

Although the sorting may have been done with the greatest care, rags and threads always make their appearance in the boiled stock. Some papers are pasted upon a body of cloth, which cannot be seen until it has been separated by the hot water of the boiling operation and the movement in the engine; others, especially threads, have been overlooked from their smallness. When the papers are reduced in the engine, it is frequently found that all these strings and rags together form considerable quantities, which must give trouble during their further progress through the chest, pump, screens, and on the wire. It is a matter of importance that they should not be allowed to pass beyond the engine, and they can be effectually caught by a very simple arrangement.

By putting the fingers upright, like a rake, into the moving pulp, it is easy to catch the rags and strings which pass that way; they will gather around and hang

on to them. This simple experiment shows what ought to be done. Instead of using the fingers of the hand, a rack should be constructed, similar to those used for water-wheels, and placed across the engine-tub, between the midfellow and front side, where the pulp begins to ascend to the roll, as represented in Fig. 18. A frame of hard wood H which is hanging in boxes on the midfellow and front side, rests with its lower part on the bottom of the engine. The upright teeth which form the rack are fastened into this frame; they must be strong enough (about 2 inches deep) to resist the pressure of the pulp. They should, at the same time, occupy as little as possible of the space through which the pulp has to pass, and may be about ½ inch thick at the back end, and not less than from 2 to 3 inches apart. The edges of the teeth which are struck by the flowing pulp should be sharp or pointed, to make the strings hang on easier. Wooden teeth answer better than metal ones, because the latter become slippery and let the strings glide off. As long as the rack is not needed, the lower end is lifted above the engine and held there by means of a stick or paddle, placed under it, across the midfellow and front side of the vat. As soon as the papers are sufficiently reduced to pass the rack without obstructing it, it is set in working position, and the strings immediately begin to gather and hang on to its teeth; it must be frequently raised to remove the rags until no more can be fished out.

We have seen bucketfuls of rags and strings thus taken from an engine furnished with imperfections or shavings, which were apparently free from them.

The washed and cleaned pulp is then bleached in the engine, in precisely the same manner as rags. If only one class of papers is used and made into a low-priced article, the whole operation can be finished in the one engine; but if the pulps of different grades of imperfections are to be mixed, and the best possible quality produced, the bleached pulp should be emptied into drainers.

Fine blue letter-paper, if a considerable quantity of it can be obtained, should only be washed, but not bleached, as its pulp furnishes a very good coloring material, which may be used in the place of ultramarine.

203. Mixing, Beating, and Final Remarks.—The pulp from waste papers is, like that from rags, mixed in the beaters, washed, and made into stuff for the machine. It requires for this purpose no severe beating, but only a thorough brushing, which will not permit any small pieces of paper to slip through without being reduced to fibres.

If strings and rags were allowed to remain among the papers, instead of having been fished out, it would be necessary to grind them into pulp; and this could not be done without beating the papers more severely than they require, thus injuring the fibres and the strength of the new paper.

If waste-paper is to be mixed with rags, the latter must be thoroughly reduced before the paper-pulp is added.

Every particle of paper which has not been thoroughly reduced to fibres, either from imperfect boiling or beating, will cause a dark, thick spot in the new paper which is made from it.

If the operations have been very badly conducted, the new paper will sometimes present a mottled appearance, or even be covered with letters or words, which had neither been dissolved nor brushed out.

Every engine of pulp, made from waste paper, should therefore be well examined before it is allowed to be discharged.

Different kinds of pulp can also be separately finished in the engine and mixed in the stuff-chest with straw or rag-pulp, especially if they are to pass through a patent pulping-engine afterwards. It has been found difficult in many mills to brush out waste-paper with ordinary beaters, and Jordan engines (Figs. 48 and 49) have therefore been generally adopted for this purpose. Nearly every mill known to us which works waste-paper as a specialty is supplied with one or more of them.

The writer, as manager of the Public Ledger Paper Mill, has, during four years, worked millions of pounds of old newspapers, prints, imperfections, &c., mixed with about an equal quantity of straw-pulp, into new printing-paper. The two kinds of pulp were either mixed in the beaters, or treated separately and mixed in the stuff-chest only.

The fibres composing waste-paper are weakened by the repeated treatment, and, like shoddy, will not produce so strong an article as they originally formed; but their color and cleanness may not only be restored, but even improved.

A large number of mills are making paper from waste exclusively, and the most successful ones do not confine themselves to news, hanging, and card, but even manufacture a very fair medium quality of book paper.

Waste-paper is a good substitute for rags, over which it has the advantage that it is already reduced and absorbs very little power.

According to quality and purity, it furnishes from 70 to 90 per cent. of its weight in new paper.

It is especially of advantage to paper-mills which have no water-power or not enough of it. If the steam which escapes from the engine is used for boiling the papers, and otherwise economized, a steam-mill will, in working waste-paper, consume comparatively little more fuel than one driven by water-power.

SECTION IV.

Straw.

We subdivide this section into:

A. Wrapping-paper.—Manufacture of white straw-paper according to Mellier's directions, and by similar processes.

B. New patented processes.

C. Treatment of straw-pulp in the beaters and on the paper-machine.—Conclusions.

A. *Wrapping-Paper.—Manufacture of White Straw-Paper according to Mellier's Directions, and by Similar Processes.*

204. Yellow Straw Wrapping-Paper.—The attention of paper-makers was attracted to straw as a substitute for rags as early as the middle of the last century. Joel Munsell states in his Chronology that the first attempt to manufacture paper from straw was made in Germany in 1756, induced by the scarcity of rags. A treatise was printed upon the subject, giving a plan for reducing all vegetables into pulp, and bleaching the same.

Yellow straw-paper was the first result of these experiments, and it was probably made many years ago in substantially the same manner as at the present time.

The straw is steeped in its original length in wooden tubs, of the same construction as those described for rags and waste-paper, but of larger size. Fresh lime is dissolved in a box or tub above them, and the diluted milk of lime thus prepared, runs down to the straw.

Steam is then admitted, and the whole mass boiled for several hours, the liquid drained and washed off, and the straw thrown out. It is thence directly furnished into engines provided with washers, cleaned as much as possible, beaten into pulp, emptied into a stuff-chest, and made into paper on a cylinder-machine.

A Fourdrinier machine would also answer, but the low price of the paper does not justify the use of so expensive an apparatus when the much cheaper cylinder-machine answers the purpose.

In the manufacture of straw wrapping or boards, it is of little importance how much cellulose the straw contains, provided it be strong and pliable, as nearly all of it, except a small proportion extracted by the lime-water, enters into the body of the paper.

205. Proportions of Fibres and Other Substances contained in Different Kinds of Straw, Esparto, and some other Plants.—If good white paper is to be made from straw, the cellulose or fibre must be produced in a pure state; and upon the proportion of cellulose which may be contained in the raw material depends, to a great extent, the commercial success of the operations.

The composition of many plants has been examined, with a view to their usefulness for the manufacture of paper, and the results of a number of these analytical tests have been communicated in the *Centralblatt für Deutsche Papierfabrication* of 1871, by Superintendent C. Schmidt, as follows:

	Foliage of Oak Trees.	Poplar Foliage.	Bean Straw.	Pea Straw.	Barley Straw.	Oats Straw.	Lens Straw.	Corn Husks, Maize Straw.	Rape Seed Straw.	Rye Straw.	Wheat Straw.
Parts which can be extracted by water, ...	25.00	28.00	10.67	46.60	11.33	20.67	27.47	17.00	14.80	2.80	7.60
Parts which can be extracted by a weak lye of potash, . .	57.00	48.36	37.42	23.24	38.24	31.62	34.16	57.03	29.80	49.08	40.43
Wax, resin, chlorophyll, . .	3.00	2.88	0.91	1.54	0.78	0.77	1.27	1.74	0.50	0.52	0.47
Fibre, ...	15.00	20.76	51.00	28.62	49.65	46.94	37.10	24.23	54.90	47.60	51.50

Esparto contains:

Water, ...	9.62
Oil, ...	1.23
Albuminous matters, ...	5.46
Starch, gum, sugar, ...	22.37
Mineral substances, ...	5.04
Fibre, ...	56.28

It is evident from the small proportion of fibre contained in leaves, and foliage, that they cannot be profitable raw materials for the paper-maker.

Corn-husks or maize-straw being very abundant in Hungary, the Austrian government was, years ago, very anxious to utilize them for paper, and millions were spent in experiments on a large scale, but without success. A glance at our table, showing only 24 per cent. fibre, explains why.

The straw of beans, peas, barley, oats, rape-seed, rye, and wheat contains enough fibre; but only that of oats, wheat, and rye, and in some localities of barley, can be procured in sufficient quantities for manufacturing. As these different varieties are treated in substantially the same manner, we shall proceed to the methods of extracting the fibres from straw, without special reference to any particular kind.

206. Mellier's Patent.—The process of slow oxidation, by which nature dissolves

decaying plants, has in a measure been imitated by often-repeated maceration of the straw, alternating with baths in alkaline lye, until the fibre was obtained pure, or nearly so.

Even at the present day white paper is made from straw, boiled with a solution of caustic soda in open tubs.

To make its manufacture a profitable business, it must be done expeditiously, with as little labor, chemicals, and fuel as possible, and with as large a production of pure fibre as can be obtained.

Numerous experiments have been and are necessary to determine what proportions and kinds of chemicals, what degree of temperature, how much time, and what mechanical apparatus are best suited to that end.

Though white paper had been made from straw as early as in the year 1800 by Matthias Koops, and later by Montgolfier, and Lemuel W. Wright (patented 1847), the manufacture had not been carried on largely until Mellier established, as the result of many experiments made by him, a simple, concise prescription, by which, when followed out correctly, good white paper could be made. The specifications of the patent, granted to him, contain a full description of his process, and, since it has given rise to considerable litigation, we add here a copy of it:

M. A. C. MELLIER, OF PARIS, FRANCE.

Letters-Patent No. 17,387, dated May 26th, 1857.

Patented in France, August 7th, 1854.
Patented in England, October 26th, 1855.

To all whom it may concern:

Be it known that I, Marie Amédée Charles Mellier, of Paris, in the Empire of France, have made an invention for an improvement in the manufacture of paper, and I do hereby declare that the following is a full and exact description:

The invention has for its object a peculiar process for the treating of straw and other vegetable fibrous materials requiring like treatment, preparatory to the use of such fibres in the manufacture of paper; and the improvement consists in subjecting straw or such other fibrous materials to a pressure of at least 70 pounds on the square inch when boiling such fibrous matters in a solution of caustic alkali. For this purpose the straw or fibrous matters are cut into short lengths, soaked in warm water, and washed. They are then placed in a suitable boiler—and I use for such purpose a rotary boiler provided with a coil or coils of steam-pipe—for the purpose of heating the contents; and I prefer that the boiling should be carried on at a temperature to produce at or about 80 pounds on the square inch in the boiler, where are the fibrous materials to be acted upon, but so high a temperature is not absolutely necessary; for I have found by experiment that it is essential that a temperature equivalent to 70 pounds on the square inch must be employed. The quantity of alkali used is at the rate of about 16 per cent. of caustic soda or potash of the straw or fibrous substance under process. The fibres may then be bleached by the use of a comparatively small quantity of bleaching powder or chloride of lime.

To enable others skilled in the art to make and use my invention, I will proceed to describe more

fully the manner of using the same: The straw, or other fibrons material reqniring a like process to prepare the same for the paper manufacture, is first, as heretofore, to be cnt, in a chaff-cutting or other machine, into short lengths, and to be freed from knots, dirt, and dust, and then steeped for a few honrs in hot water. The straw or fibrous materials and a weak solution of caustic alkali are then to be placed in a suitable close boiler, heated by steam as hereafter explained, and the heat is to be raised to snch a degree as to attain and maintain for a time a pressure internally of the boiler eqnal to or exceeding 70 ponnds on the square inch—that is, abont 310 degrees of Fahrenheit—by which means a considerable saving of alkali, as well as time and fuel, results, as compared with the means of using a hot solution of caustic alkali, as now practiced in preparing straw and other fibres for paper-making.

The boiler employed for the purpose, and the manner of heating it by steam, may be varied; but, first, it must have a rotary motion, either on its long or on its small axis, by means which are very well known; and second, I prefer not to send the steam directly into the liquid in which the materials are immersed, bnt to pass it either in a jacket around the boiler, or through a coil or a system of steam-pipes inside of it, so that the steam does not mix with the caustic alkaline solution in the middle portion of the boiler, but is kept separate, and does not therefore, in condensing, dilute the canstic alkaline solntion nsed.

The plan of constrnction of the boiler I would recommend would be, if the boiler is to rotate vertically or on its small axis, as very well known, to cover it with a jacket, so that the steam could circulate from one end to the other between the two plates; or rather, if it is to revolve horizontally, or npon its long axis, as is equally very well known, to fix near each end of the boiler and inside of it a diaphragm or partition, which partitions are connected together by numerous tubes, which are arranged in a circle, near the outer circumference of each partition. By this arrangement the steam is introduced through the hollow axis at one end of the boiler, and it passes through the steam-pipes, and thence into the compartment at the other end of the boiler, where it and the condensed steam are conveyed away, as is well understood, through the other hollow axis.

In adopting the plan of not sending directly the steam into the boiler, I found the three following advantages: first, not to dilute, as I have already said, the alkaline solutions: second, to avoid the trouble of having sometimes the end of the steam-pipe in the boiler choked with straw, and to prevent, in case that by one cause or another the pressure in the steam-boiler would fall under the degree of the pressure in the straw-boiler, the priming of the first by the second, viz., the absorption of straw and alkaline solution from the straw-boiler into the steam-boiler; third, the greater facility of cooling the straw-boiler, when the pressure has been maintained for a snfficient length of time, by means of turning off the steam at one end, letting it at the other end ont of the jacket, or of the coils or steam-pipes just described, and passing through the same a stream of cold water, which, at the same time that it cools the mass, furnishes a quantity of cold water, which can be received in convenient vessels, and will be found very useful for washing the straw or other fibrons material after boiling.

By means of submitting the straw or similar fibrous materials to a pressure of between 70 to 84 ponnds on the square inch inside of the boiler, I can reduce considerably the proportion of alkali; and the solution which I prefer to use is to be from 2 to 3 degrees of Baumé, or of a specific gravity of from 1.013 to 1.020, and at the rate of about 70 gallons of such solution to each hundredweight of straw or other fibrous vegetable matters requiring like treatment.

The boiler is to be filled with straw and the alkaline solution, and then closed, fluid and steam-tight. The boiler is made to revolve slowly—say abont 1 or 2 revolutions per minute—and the steam is to be admitted. I find it desirable to keep up the heat and pressure dnring about three hours after the pressnre above mentioned has been obtained, when the process of boiling is complete. A steam-gauge, properly fixed upon the boiler, will enable one to ascertain when the pressure has attained the required degree.

When the apparatus and the fibres under process have been cooled by the means hereinbefore mentioned, or rather, when the pressure has been reduced to nothing, I open the manhole of the boiler, empty the materials in suitable vessels, and wash them first with hot water, then with cold water, nntil

the liquor runs perfectly clear. I then steep the fibre for about an hour in hot water acidulated with a quantity of sulphuric acid equal to about 2 per cent. of the weight of the fibres under process, and finally, the washing is completed with cold water. The straw or fibre may then be bleached in the ordinary manner, and it will be found to be accomplished by a comparatively small quantity of chloride of lime.

Having thus described the nature of my said invention and the manner of performing the same, I would have it understood that I do not claim the general use of caustic alkaline solutions, nor the employment generally of a close boiler for boiling straw or other vegetable fibrous substances.

But what I claim as my invention and desire to secure by letters-patent is, the use of a solution of caustic soda (NaO) in a compartment of a rotary vessel, separate from that which contains the steam-heat, substantially as described.

I also claim the within-described process for bleaching straw, consisting in boiling it in a solution of pure caustic soda (NaO) from 2 to 3 degrees Baumé, at a temperature not less than 310 degrees Fahrenheit after it has been soaked and cleaned, and before submitting it to the action of a solution of chloride of lime from 1 to $1\frac{1}{2}$ degrees, substantially as described.

AM. MELLIER.

The American Wood-Paper Company are the owners of this and many other patents, and claim, as the general manager, Mr. Ladd, stated to the author, the exclusive right to use caustic soda, with or without pressure, for the preparation of straw and wood pulp. The company have tried to enforce their claims through the courts, but have naturally enough encountered strong opposition. Mellier's original patent expired in 1868, and the defendants argue that the extension, dated July, 1868, has been illegally obtained and is therefore void. The case is now before the Supreme Court of the United States, and there is no reason to doubt that a just decision will be rendered in time. The claims, if admitted, will give to the American Wood-Paper Company the monopoly of a large part of the paper trade, and many new enterprises are probably awaiting the result.

We shall now discuss the operations of a mill making white paper from straw on Mellier's plan, or in a similar manner.

207. Purchase and Storage of Straw.—The purchase of straw, simple as it seems, requires some judgment and a knowledge of the country from which the mill draws its supply. Wherever land is of little value, or held in large tracts by only a few proprietors, the harvest of grain is mostly so abundant that houses or covers, large enough to shelter it, are seldom met with. The thrashing is done in the open fields, as fast as possible, and the straw, being considered of little value, is piled up carelessly. Such straw contains usually more impurities, chaff, grain, and weeds, than that produced on small farms, the owners of which give their personal attention to every department, trying to make up by the quality of their produce for the deficiency in quantity. Where the land is valuable and divided into small estates, nearly every farm has a large barn or shed, wherein the grain harvest is stored and thrashed during the winter. Even the soil is better taken care of; the straw is free from weeds, clean and bright, and fully worth the higher price which it commands.

If straw remains exposed to the weather for any considerable length of time, it

undergoes a change, which is indicated by the color; it gets continually darker, until it has finally turned perfectly black.

It may be only partly rotten, and yet retain many sound fibres, but the colored substance, by which they are surrounded, seems to withstand the action of the chemicals which are used to subdue the straw, and prevents the production of a white pulp. Experiments have proved that this coloring substance is soluble in water, but few or no mills are supplied with the machinery which would be required to wash rotten straw thoroughly before it is boiled or subdued, and unless this is done, it is not only worthless itself, but injures the quality of the paper made of the good straw, with which it may be mixed.

It is necessary that straw should be under cover to remain bright, and if large quantities have to be kept on hand, it will pay to build sheds, or roofs supported on posts for the purpose.

The loaded teams, being driven under it, can be emptied with forks, suspended on pulleys fastened to the roof, which may be worked by the team-horses. The double harpoon fork has been used by the author for this purpose.

Sheds or ricks of this kind should be about 100 yards distant from the mill, as the fire insurance companies hold that the proximity of large quantities of straw increases their risk and consequently their charges.

The husks of grain, the chaff, and the leaves or blades, which are attached to several kinds of straw, contain very little fibre; they are not only of little value, but also occupy the place of better material, and absorb labor, chemicals, and fuel, without giving any adequate return.

It is the farmer's aim to separate all the grain from the straw, but, even with the best thrashing-machines, this cannot be done thoroughly if the straw has been cut green, or if it is thrashed in a hurried manner, as it is, for instance, in most cases where the operation is carried on in the fields. Any corns or grains, which have entered the boilers with the straw, are subjected to the action of heat and water, and the starch, of which they principally consist, is thereby transformed into dextrin or gum, and perhaps partly into sugar. We find frequently in white straw-paper small transparent spots, similar to those made by oil; they will in most cases be found to be dextrin produced from grain, or from parts of grain attached to chaff.

After the grain or chaff has once been admitted to the boiler, it will become decomposed, and cannot afterwards be caught in the screens with other impurities. We have visited a mill where all the straw, after being cut, was passed through a cleaner, and, although it had been originally in very good condition, yielded enough grain to provide food for six horses.

The straw is often wet and heavy, and if the purchaser does not make a deduction for the increase of weight, the farmers will find it to their advantage to expose it to rain. We have known some of these gentlemen to assist nature by pouring pails of water over the straw.

The stem or tube of the straw is the part of the plant which is richest in fibres,

while the blades, leaves, and chaff contain very little, and decrease the general yield by their presence. Our table shows that wheat-straw is richer in fibres than that of rye or oats.

Clean, bright wheat-straw gives, according to the author's experience, as much paper as that of rye, but the latter is generally furnished to the mills cleaner and with fewer weeds and blades than either wheat or oat-straw, and for that reason gives better results; hence, many manufacturers conclude that it contains more fibres.

We consider the quality and purity of the straw as of more importance than the species; clean, bright, white straw is preferable to a poor article of rye-straw, and *vice versa.*

Oat-straw has more worthless blades attached to it than either wheat or rye, and is therefore, everything else being equal, less valuable.

The quality of the straw varies with the soil and the climate, and, even for the same soil, in different years.

Large cities are heavy consumers of straw, and draw their supplies from considerable distances; it is pressed in bales like hay for this purpose, but from its great elasticity cannot be much reduced in bulk, which makes its transportation very expensive.

Mills at some distance from large cities, in the midst of a grain-growing country, cannot merely buy cheaper, but can also save the cost of baling all the straw which may be furnished by the immediate neighborhood.

It is, however, a mistake to suppose that a mill has all the conditions of prosperity, if located in a country where straw is abundant and seemingly of no value. As soon as the mill creates a demand, the price goes up, and as it takes a large belt of country to supply an ordinary mill, the transportation of at least a part of the straw will often double and triple its cost. While straw may be cheap in a certain locality, the transportation of coal, chemicals, paper, &c., may be so expensive as to outweigh this advantage. (See Chapter VI, Section XII, Location of Mills.)

208. Cutting.—The first operation to which straw is subjected in most mills is that of cutting it into short lengths. The cutters used are similar to rag-cutters; they have a table on which the straw is spread and fed to fluted feed-rolls, which push it forward over a horizontal bed-knife with steel edge.

Revolving knives fastened to a solid horizontal cylinder, like those used for rag-cutters, form scissors with it. The relative speed of the feed-rolls and of the knives determines the length of the pieces cut.

It will pay in most cases to put the straw through a cleaner, but if this is not done, it is well to let the cut straw drop from the knives on to a rack or wire with openings, through which the chaff and grain can pass while the straw is kept on top. The efficiency of this separator can be increased by giving it a slight shaking motion; it is placed inside of the cutter, requires no room and very little expense.

The cut straw must next be boiled with caustic soda. The preparatory operations, such as boiling in hot water or waste liquor, will be spoken of hereafter.

209. Soda.—The preparation of the solution of caustic soda, which is used for the digestion of straw, wood, esparto, and of nearly all the plants which serve as substitutes for rags, is of the greatest importance, and cannot be too well understood.

Carbonate of soda (NaO,CO_2) is a combination of oxide of sodium (NaO) with one of carbonic acid (CO_2) atom for atom.

During the last century it was extracted from the water of some lakes, and from the ashes of plants growing on the sea-shore. The trade in this article was nearly altogether in English hands, and when the first Napoleon closed the continent of Europe, as far as his power extended, to the English trade, he offered, at the same time, a prize for the discovery of a method, by which soda could be manufactured cheaply and in large quantities from other materials.

Leblanc's process was the result, and is used at the present day substantially on the principles laid down by the inventor.

Common rock salt, chloride of sodium ($NaCl$), is treated with sulphuric acid (SO_3,HO), and transformed into sulphate of soda (NaO,SO_3); the hydrochloric acid (HCl) which escapes is gathered and utilized in the manufacture of bleaching-powders.

$$\underbrace{NaCl}_{\text{Chloride of sodium.}} + \underbrace{SO_3,HO}_{\text{Sulphuric acid.}} = \underbrace{NaO,SO_3}_{\text{Sulphate of soda.}} + \underbrace{HCl}_{\text{Hydrochloric acid.}}$$

The sulphate of soda thus obtained is well mixed with coal or carbon (C) and with carbonate of lime (CaO,CO_2) or chalk, and heated in a furnace.

The mixture is thereby transformed into soluble carbonate of soda (NaO,CO_2), and a double salt consisting of sulphuret of calcium and lime ($3CaS,CaO$), while oxide of carbon (CO) escapes.

The following equation shows the transformation:

$$\underbrace{3(NaO,SO_3)}_{\text{Sulphate of soda.}} + \underbrace{4(CaO,CO_2)}_{\text{Carbonate of lime.}} + \underbrace{13C}_{\text{Carbon.}} = \underbrace{3(NaO,CO_2)}_{\text{Carbonate of soda.}} + \underbrace{3CaS,CaO}_{\text{Double salt.}} + \underbrace{14CO.}_{\text{Oxide of carbon.}}$$

By treating this *black ash* with water, the carbonate of soda is dissolved, while the sulphuret double salt remains solid. The solution is drawn off, evaporated to dryness, and the soda ash obtained as a white-grayish mass.

This soda ash is not pure—some sulphuret and chloride of sodium are mixed with it; but if it is again heated with carbon, redissolved and concentrated by partial evaporation, the carbonate of soda will crystallize from the solution.

The crystals thus obtained are pure carbonate of soda, with about 63 per cent. of water; they contain therefore less soda in the same weight than soda ash, and are, as compared with the latter, too expensive to be used for the digestion of straw.

The United States draw nearly their entire supply of soda from England, and the following remarks, from Dr. Sheridan Muspratt's work on Chemistry, which illustrate the difficulties encountered by the pioneers in its manufacture in that country, may therefore prove interesting to the reader:

"The greatest source of soda, both as applied to the manufacture of soap and to all other purposes, is the *white ash* or soda ash of commerce, produced by the decomposition of common salt. The introduction of this material, though it was effected with much difficulty, has been the greatest stimulus the soap manufacture has ever received. Mr. James Muspratt, of Liverpool, who was the first to carry out Leblanc's process on a large scale, in the year 1824, was compelled to give away soda by tons to the soap-boilers before he succeeded in convincing them of the extraordinary advantages to be derived from it. As soon, however, as he effected this, and when the soap-boilers discovered how much time and money they saved by using artificial soda, orders came in so rapidly that the editor's father, to satisfy the demand, had his crude soda discharged red hot into iron carts, and thus conveyed to the soap manufactories."

210. Caustic Soda—its Purchase and Test.—Caustic soda is oxide of sodium (NaO), or carbonate of soda deprived of carbonic acid; it is always combined with water to hydrate of soda, draws carbonic acid from the air with great avidity, and is thus retransformed into carbonate so easily that it can only be preserved in hermetically closed vessels, made of a material which is able to withstand its destructive influence. It is shipped in iron barrels as solid hydrate of soda, and sold in that form to other trades; but paper-makers find it mostly cheaper to prepare their solutions by causticizing soda ash with lime. We know, however, one large firm who watched the market closely, and finding, at one time during the late war of secession, the relative prices of caustic soda and soda ash to be such that they could substitute the former for the latter, effected a considerable saving by its use.

From 10 to 20 per cent. only of the so-called *caustic soda ash*, which is generally used in paper-mills, is really (hydrated) caustic soda (NaO); the soda ash being more valuable in proportion as it contains more of the latter, because it is free from carbonic acid and does not require to be causticized.

Soda ash is usually shipped in hogsheads, containing from about 1500 to 2000 pounds, which, through pores and cracks, permit to some extent the access of air, whereby the caustic soda, which may form part of it, is retransformed into carbonate, if a sufficiently long time elapses between its manufacture and consumption.

The standard strength—as accepted by the trade—of so-called *caustic soda ash*, or of the carbonated kinds, is 48 per cent., which means that there should be 48 pounds of oxide of sodium (NaO) contained in 100 pounds of ash. Of all the components of soda ash, the oxide of sodium (NaO) is alone of value to the paper-maker; he expects and is entitled to receive 48 pounds of it in 100 of ash; but if the proportion of NaO is larger, it is also just that the purchaser should pay for the excess at the same rate as for the regular 48 per cent. If the soda ash is, for instance, of 54 per cent., it contains 6 per cent. or one-eighth above the regular 48 per cent., and is sold accordingly at nine-eighths of the market rate.

Soda ash does not, like bleaching powders, lose strength in contact with the air; but it may increase in weight by taking up water and carbonic acid, the latter uniting with the hydrated caustic soda (NaO,HO) and changing it into carbonate of soda. The purchaser should therefore insist on paying only for the original invoice weight, or, if the actual weight is charged, he ought to have the soda ash tested again, and

accept as 100 pounds only a quantity which contains 48 pounds of oxide of sodium (NaO).

It is useful in all cases to have a test made of every large lot purchased, and, for the benefit of those who wish to do it themselves, we shall explain a simple method for it. It is called the

Alkalimetrical test, and is based on the reaction of alkalies and acids on litmus color. The alkalies, of which soda is one, turn the red color of litmus blue, and acids turn the blue color red.

If to a solution of soda just enough sulphuric acid is added to neutralize it, so that only sulphate of soda remains, neither the blue nor the red color will be changed by the solution.

A test liquid of pure monohydrated sulphuric acid must be prepared and so diluted that one degree or volume of the alkalimeter—a graduated glass vessel, from which it is measured out—neutralizes exactly one grain of oxide of sodium or anhydrous (caustic) soda (NaO).

A weighed quantity of the soda ash which is to be examined, is then dissolved, colored with a few drops of blue litmus solution, and enough of the test acid poured slowly into it from the alkalimeter to neutralize the soda. The blue color of the liquid changes into red as soon as this point is reached, the operation is then finished, and the number of degrees of the test acid, which have been used, corresponds with an equal number of grains of soda (NaO) contained in the weighed sample.

Commercial soda ash is not pure; it contains some sulphuret and chloride of sodium; but the diluted acid used for the test leaves the latter unchanged and only combines with the oxide of sodium (NaO) of the carbonated and of the caustic soda.

211. Preparation of the Solution of Caustic Soda.—It is essential that the soda ash should be rendered caustic—that is, set free from combination by the removal of carbonic acid—as, if it be in chemical union with any other body, it has no decomposing power over the oils and many other substances. Even if combined with the weakest acids, saponification will not ensue; and the greatest care should therefore be exercised in this preliminary process,—the preparation of the lye.

The process of causticizing depends upon the greater affinity of lime than of soda for carbonic acid, and the decomposition is one of the most simple, as shown by the following equation:

$$\underset{\text{Carbonate of soda.}}{NaO,CO_2} + \underset{\text{Lime.}}{CaO} = \underset{\text{Carbonate of lime.}}{CaO,CO_2} + \underset{\text{Soda.}}{NaO.}$$

Caustic lime, which is fresh-burnt lime or oxide of calcium, is used for this purpose; the carbonic acid leaves the soda and joins the lime, forming the insoluble carbonate of lime.

Caustic lime or oxide of calcium is very slightly soluble in water, and must therefore be kept agitated, so as to be in contact with every part of the solution while the process of causticizing is going on.

The mixing-pans may be constructed like those for bleach liquor, represented in Figs. 38 and 39, with the difference only that they must be of iron (sheet iron), as caustic soda would destroy stone as well as wood. The receiver should be large enough to hold at least the contents of one set of two or three pans.

An iron or brass valve must be provided in the bottom of each pan, to let out the sediment of lime and soda impurities after each operation; this lime may either be conducted into the tail-race, creek, or river, to run away, or into cisterns to be saved and utilized.

Large pieces of burnt lime, if admitted into the pans, would obstruct and break the agitators; the lime should therefore not be allowed to come in contact with the agitator as long as it is not dissolved.

A sheet-iron basket of about 2 to $2\frac{1}{2}$ feet diameter, about 2 feet deep, with flat bottom, and perforated with numerous holes of about $\frac{1}{4}$ inch diameter, is hung up by two iron handles on an iron bar laid across the pan; the agitator not being high enough to reach the basket.

The pieces of lime are gradually furnished into this basket, the pan is filled with water, and heated to boiling by the introduction of steam. The hot water reaches the lime through the holes, transforming it into lime-milk, while the cinders or unburnt stones remain in the basket and are removed with it. The soda ash is then added, and the whole mass kept agitated and boiling for three to four hours, when the agitator is stopped and the steam-valve closed. After some hours of rest, the suspended carbonate of lime will be found settled at the bottom, and the clear liquid can be drawn off into the receiver by lowering gradually the pipe E (Fig. 38).

The sediment is yet impregnated with solution of caustic soda, which must be extracted; the pan should therefore be again filled with water, the agitator put in motion, and the boiling recommenced. While a fresh solution is made in one pan, a second or weak extract is boiled in the other, and both are united in the receiver.

In some mills the first solution is made so concentrated that even a third extract is required to exhaust the sediment. If the second solution produces a liquid testing more than $1\frac{1}{2}$ degrees Baumé, a third one may be of advantage; otherwise the amount of soda saved would hardly pay for the labor and steam spent on it.

If the preparation of fresh soda solution is to go on continually, one more mixing-pan is also to be provided for every additional extract.

It is necessary that the liquor in the receiver should be of the same strength all the time; great care must therefore be taken that a strong extract be always united with a weak one, or with two, if as many are made of every sediment.

When the operation is finished, the lime on the bottom of the pan is, with the aid of the agitator, mixed with water and allowed to run off through a valve and spout. In most cases this lime goes to waste, but it might be conducted into receivers, freed from most of the water by draining, and burnt again; this would be especially of advantage where lime is dear and fuel cheap.

Muspratt points out, in an article on the manufacture of soap, an additional advantage, which may be gained by such a recovery:

"A fact deserving of mention in treating of the preparation of lyes is, that in the process of causticizing by means of lime, a portion of the soda appears to enter into some form of combination very difficultly soluble. Mr. Kynaston, a student of the editor's (Muspratt), lately examining the calcareous deposit, found it to contain, after being well washed, soda to the amount of 5 or 6 per cent. When the deposit, after being dried, is heated to a temperature insufficient to expel carbonic acid, and, after being allowed to cool, is again drenched with water, caustic soda is then removed with great ease, and the deposit may be almost completely deprived of soda. Taking these facts into consideration, the editor is of opinion that it would well repay the soap manufacturer to collect the lime deposit, and, after thorough desiccation by exposure to the air, to submit it to heat until the carbonic acid is expelled. The lime, now again become caustic, may be used advantageously in the preparation of fresh lye; and the process may be repeated until the deposit becomes highly charged with the impurities of the ash, when fresh lime may again be used for a new process."

If this method for the recovery of the lime is not adopted, it is advisable to drain it in receivers to such a consistency that it can be mixed with the deposits from wash-water settled in pits or ditches, and with offal of all kinds, into a valuable compost-manure. The author has recovered lime for this purpose by simply running it into large, rough boxes, through the cracks of which the water could drain off, leaving the lime dry enough to be thrown out with shovels.

It is better to use an excess of lime rather than to run the risk that some of the soda will remain in the solution as carbonate, and, consequently, fail to assist in the dissolution of the incrusting matters of the straw.

Burnt lime contains quantities of caustic lime (CaO), which vary according to the quality of the stone from which it is made and the care taken in burning it; the proportion of caustic lime in it will usually amount to from 50 to 90 per cent. It attracts quickly moisture and carbonic acid from the air, especially if divided into small pieces or dust; the best lime, and in lumps, will therefore mostly be found the cheapest, and it should be used as fresh as possible.

The theoretical quantity of pure caustic lime, required to causticize 100 pounds of soda ash of 48 per cent., is only 43 pounds; but our lime is neither pure nor perfectly caustic, and from 60 to more than 100 per cent. (in most cases pound for pound or 100 per cent.) have to be used in practice.

As the limestone may at different times, even in the same kiln, be differently burnt, and as the lime may have been stored during a longer or shorter time, and consequently have absorbed more or less carbonic acid from the air, the proportion of caustic lime or oxide of calcium, contained in a certain weight of it, may change almost every day, and it is therefore necessary either to test every new soda solution as to its causticity, or to use a large excess of lime, or to run the risk of wasting soda by not depriving it of its carbonic acid.

The test is easily made by proving the presence of carbonate of soda in the solution, which, if found, is an evidence that the operation has been imperfectly per-

formed, and should be repeated, with a fresh addition of lime, until all the carbonate is transformed into caustic soda (NaO).

We take, after the lime has all settled down, from the clear liquid a glass tumblerful without creating the slightest motion in the pan; let the tumbler stand for about fifteen minutes in a quiet place, so that any carbonate of lime which may yet be suspended in it will fall to the bottom; and then pour into it a few drops of sulphuric acid. If carbonic acid is contained in the solution as carbonate of soda, the acid will drive it out by taking its place and forming sulphate of soda.

The escaping carbonic acid gas rises up in bubbles as in soda water, and as long as the liquid shows such effervescence on the application of the acid test, the quantity of lime has not been sufficient, or the boiling has not been done in a thorough manner. Any workman of ordinary intelligence can be taught to make this test, and prepare the solution so that no carbonic acid can be discovered in it.

Care must only be taken that not a particle of carbonate of lime should be suspended in the test-liquid, as the vitriol would set its carbonic acid free, and deceive the operator. To be quite certain of it, the test-liquid may be passed through a paper filter.

The continued application of the test not only determines the exact quantity of lime which is necessary to causticize any given quantity of soda ash, but it is also so instructive to the operator that he will soon be enabled to judge the lime from its appearance, and guess the correct proportion at once.

It has been found that very concentrated solutions of caustic soda take up some carbonic acid from the carbonate of lime on the bottom of the pan, and are thus partially retransformed into carbonate of soda. But, as solutions of such high concentration are seldom required by the paper-manufacturer, this danger can easily be avoided by providing capacious pans, which will hold at least from 8 to 10 pounds of water for every pound of soda which is to be dissolved in them.

If a very strong solution should be required, the first extract alone is to be drawn off into the receiver, while the following weaker ones are to be used on a fresh lot of soda in the place of water.

A practical comparative test of different brands of soda ash can easily be had by making the same quantity of solution from the same number of pounds of each kind, and testing both at the same temperature with the hydrometer. The one which shows the highest specific gravity is the best for the digestion of straw.

212. Digestion by Boiling.—Boilers, similar to those used for rags, revolving horizontally on their long axes, are frequently employed for the digestion of straw, but they are either heated by direct fire, or with steam circulating through a jacket or a system of pipes. In a few mills straw is boiled in the same manner as rags, by the direct introduction of steam into the liquor; but Mellier is quite right in condemning this method. The steam in condensing dilutes the liquor and makes it continually weaker, while it should become stronger towards the end of the operation, in order to dissolve those incrusting matters which have up to that time withstood the action of

the lye. It is the author's experience that, everything else being equal, more soda ash is required when steam is introduced directly.

The application of direct fire to rotaries is objectionable, because some of the straw may adhere to the shell, and become burnt or charred by the continued exposure to an intense heat; the damage from this source may even be considerably increased, if the movement of the boiler is unexpectedly interrupted by a break in the gearing or a stoppage of the motor.

A boiler of 16 feet length and 6 feet diameter will hold 2500 to 3000 pounds of well-packed and short-cut straw.

This quantity cannot be gotten into a boiler of that length unless it is stowed away by two or three men inside, as soon as it is put in through the man-hole. In hot summer days this labor, performed in more or less heated boilers, is suffocating and very severe upon the operatives.

The boiler, being filled with a weighed quantity of straw, receives its portion of soda solution through a pipe, which starts from the liquor-receiver, and enters through the centre of one of the journals.

If possible, this receiver, as well as the mixing-pans, should be located at some height above the boilers, so that the solution will run in quickly, impelled by gravitation. If the boilers are situated above the receiver, the liquor has to be pumped into them.

The man-hole having been closed, the boiler, which now contains its full charge, is put in motion, and the fire or steam started and kept up until a certain pressure, indicated by a gauge, has been reached and sustained for the prescribed length of time. Most of these boilers have a perforated false head or diaphragm, a few inches from the solid head, and between the two extends a stationary pipe nearly to the bottom, and another one nearly to the top, both passing through the journal, and communicating with pipes outside.

The liquor is forced out through the lower pipe by the inside pressure, and necessarily carries off a considerable quantity of fine fibres, which in most mills are entirely lost. The stronger the pressure the heavier the loss, and to reduce its violence, a portion of the steam is allowed to escape through the upper pipe before the lower one is opened.

Two or three of these boilers are sometimes connected for the purpose of saving fuel, by blowing out the steam from one into the other, until the pressure is alike in both.

Steam and liquor being blown out, the man-hole is opened, the boiler put in motion, and emptied through a trough into a large vat or tub, while fresh water is admitted through the pipe in one of the journals, to assist the discharge of the mass.

In filling the boiler, portions of the straw are sometimes scattered outside, and are carried into the tub by the emptying fluid without having been digested.

Straw in its original form, if allowed to get into the pulp, would cover the paper with yellow spots, but fortunately it floats on the surface in the tub, and can be taken off with a skimmer similar to those used in kitchens, but of larger dimensions.

213. Washing.—The vat or tub is provided with a false perforated or drainer-bottom, covered with bagging or cocoa-matting, through which the liquid can escape. A large stream of water should be admitted under this false bottom, through which it will rise, mixing with the pulp and carrying it up. By stirring the thus diluted contents with paddles, allowing them to drain again, and repeating the operation often enough, the pulp can be pretty well washed.

A good washing-engine is, however, the best washer for any kind of pulp, and may be used either alone or in addition to the described wash-tub. If the half-stuff is allowed to be drained in the tub, it must be taken from it and carried to the engine in boxes running on trucks; but if it is kept diluted and fluid enough, it may be pumped into the engine either directly from the wash-tub, or from a receiver into which the latter has been emptied. A common, good-sized fan-pump with two wings, making 500 to 1000 revolutions per minute, will perform the work quite satisfactorily; it should be connected in as straight a manner as possible by means of 5- or 6-inch pipes, with the tub or receiver as well as with the engine, so that the pulp may flow into it from the former, and be forced to the latter without furnishing an opportunity for deposits to take place in corners or bends, which would obstruct its passage.

The pump is put in motion whenever the engine is to be filled, but it is idle during the remainder of the time, and should therefore be provided with tight and loose pulleys or with a belt-tightener.

Some of the substances dissolved in the hot soda solution are not soluble in a cold one. To prevent them from again assuming the solid state and combining with the straw fibre, Mellier prescribes the use of hot water for the first part of the washing operation.

It is, however, practiced in those mills only which have an abundance of hot water, especially in steam-mills, where the water is heated by the steam which escapes from the engines. The steam, which is blown off from the straw-boilers, would, if conducted through a water-reservoir, heat a considerable quantity of water, which might be used for this purpose.

If any alkali is left in the pulp, it will cause a loss of chlorine by uniting with the latter in the subsequent operation of bleaching. Mellier adds therefore about 2 per cent. of the weight of the fibres, of sulphuric acid, and washes again afterwards. This is certainly correct, but takes time, and most paper-makers content themselves with acidifying the pulp immediately before bleaching, so that the surplus acid will combine with the lime of the bleach-solution.

If the straw has been well digested, and its fibres are freed from all incrusting and intercellular matters, they will be fine and short enough to dispense with any mechanical reduction by grinding, and the washing-engine may therefore be supplied with a smooth bed-plate and blunt fly-bars; sharp knives should not be allowed in the plate or on the roll.

From the washing-engine the pulp is emptied either into drainers or into a stuff-chest. In the first case it is taken from the drainers and treated like rag pulp, but

if emptied into a large stuff-chest provided with an agitator, it is done for the purpose of running it over a wet-machine.

214. **The Wet-Machine**, represented by Figs. 92 and 93, consists of a screen or pulp-dresser, and of a forming-cylinder and first press, or, in other words, of the whole wet part of a cylinder-machine except the second press. The upper press-roll is provided with a scraper, which prevents the pulp from going round with it, and a stuff-pump forwards the pulp from the stuff-chest to the wet-machine in the same manner as to a cylinder-machine. The pulp should also pass over a sand-table, on which heavy impurities, which cannot fail to be mixed to some extent with straw, may deposit themselves.

It is not necessary that the machine should furnish either a continuous web, like paper, or a very dry one, and a wooden press-roll may be used in place of the upper iron one, or for both the upper and lower one; the felt is subjected to less friction from the lighter wooden rolls and lasts longer.

The pulp on leaving the felt drops into a receiving-box, and is now ready for bleaching.

If wash-water is supplied in abundance, it will be preferable to let the water, which leaves the pulp through the forming-cylinder and fan-pump, run off into a drainer or stuff-catcher, for the recovery of any fibres which may be contained in it, instead of pumping it back to be mixed with a fresh lot of pulp. Its place had better be supplied by clean water, and the pulp thus made to undergo an additional washing-operation while on the wet-machine.

The wet-machine should be constructed so that the worn-out wet-felts of the paper-machine will fit it, in order to avoid a necessity for the purchase of new ones.

The screen retains all the knots and other parts of the straw which have not been thoroughly boiled, and is invaluable as a cleaner and as a corrector of all previous mistakes, and, to some extent, of imperfect digestion.

The knots or screenings, which have been removed from the pulp-dresser, may be either boiled by themselves a second time, or returned to the boiler with a fresh lot of straw, or used for wrapping paper.

A wet-machine also occupies less room, and produces the pulp more uniformly and more quickly than drainers, and is almost indispensable for the manufacture of white paper from vegetable fibres. It may even with advantage be used for rag-pulp.

Straw would have to undergo a costly sorting and cleaning process before being put into the boilers, if it were not subsequently passed through a wet-machine; and, although the latter takes the place of sorters, cleaners, and drainers, it is yet so easily managed that it only requires the supervision of one boy.

215. **Bleaching.**—The pulp is usually bleached in the engine like rags, but we shall speak of new patented methods in a subsequent article.

The art of making paper from straw consists principally in the extraction of the pure fibre, the bleaching being comparatively easy.

The quantity of bleaching-powders required for the purest straw fibres is considerably larger than for those of rags. (Particulars will be found in article 228.)

216. Revolving Straw-Boilers.—It has been found that the revolving motion of such boilers as have been described causes a considerable amount of friction between the iron sides and the straw and among the straw itself, and that the loss of many fine fibres in the following operations of washing and bleaching can be traced to this source.

It is certainly preferable to move the straw as little as possible, or not at all, if a perfect circulation of the soda solution through a large body of it can be produced in some other way. The difficulties of filling horizontal rotaries, which we have already described, and the hard labor which they necessitate, are alone sufficient to direct the attention of manufacturers to other methods for the accomplishment of the same result.

217. Steam-Pressure.—Mellier prescribes in the specification of his patent a temperature of at least 310 degrees Fahrenheit, corresponding with a steam-pressure of over 70 pounds to the square inch.

American steam-gauges generally indicate 0 when no steam-pressure is acting upon them, while the French ones show in the same place about 15 pounds, or the ever present weight of the atmosphere. Consequently Mellier's 70 pounds of the French gauge are equal to about 55 pounds of the American gauge.

There is no doubt that good paper is made from straw by strictly carrying out Mellier's directions; but, valuable as they have been for the progress of the art, they do not constitute the only method by which this can be done. There are many roads leading to Rome.

It has already been said that nature dissolves the intercellular matters without either a high temperature or a concentrated alkaline solution. Caustic soda, temperature, and time are the agents used for the digestion of straw, and by an increase of one or two of them, for instance, by the use of more time or soda, or both, the temperature or pressure may be reduced.

Mellier recommends 16 pounds of caustic soda for 100 pounds of straw. 100 pounds of standard soda ash contain only 48 per cent. of caustic soda (NaO), and 16 pounds of caustic soda correspond therefore with $33\frac{1}{3}$ pounds of soda ash of 48 per cent., or $33\frac{1}{3}$ pounds, or one-third of its weight in soda ash, are to be used for 100 pounds of straw.

We have no hesitation in saying that, with such a quantity of soda, straw may be well digested at pressures considerably less than 55 pounds above the atmosphere. Good white paper has been and is manufactured from straw by digestion in open vessels without any pressure, but there is no doubt that a high temperature, such as is recommended by Mellier, is, if not indispensable, yet of great assistance, and economical.

Steam-pressure is, however, not the only means by which a high temperature can be produced; superheated steam of low pressure will answer as well.

The steam-pressure is usually kept up from about three to six hours, and this, with the time required for filling, raising the steam, blowing off, emptying, cooling

off the boiler so that men can go in, brings the period of one operation—that is, from filling to refilling—to at least twelve to fifteen hours.

218. Pressure Gauges.—It is necessary that the pressure in the boiler should be indicated outside, and a small wrought-iron pipe connects therefore the stationary blow-off pipe, and through it the interior of the rotary, with a steam-gauge. The spring-tube gauges used for steam-boilers are not suitable for this purpose, because the alkaline liquors may accidentally reach the spring-tubes, by which they are operated, and gum them up, so that they will not indicate the pressure with accuracy. The operator, not aware of this fact, may, deceived by the gauge, raise unintentionally a higher pressure than the boiler can bear, and cause an explosion.

It has been stated that even the alkaline vapors will affect the spring-tube.

Gauges in which the steam acts directly on mercury are generally used for straw-boilers; but as they are exposed to breakage and to the loss of mercury, it is necessary, to connect the boiler also with a safety-valve, which prevents the pressure from rising beyond the desired limit.

219. Breaking down the Straw.—Mellier recommends the use of 70 gallons of solution for every 100 pounds of straw; but it is evident that more or less liquid will be required as the straw occupies more or less space, and it has therefore always been the aim of paper-makers to reduce the bulk of the straw.

It is principally for this reason that it is cut into short pieces, as it can be more closely packed in that form. Mellier steeps it also in hot water before it is put into the boiler.

The object of the application of liquids is to deprive the straw to some extent of its elasticity, or to *break it down*, and, though even cold water will assist in reducing its volume, nothing, except boiling, will do it as effectually as a solution of alkali. The liquor, which has already been used, is therefore frequently blown out into a receiver, from which it is drawn off into large tubs, filled with cut straw, well mixed with it, and finally discharged through a perforated false bottom and an outlet-valve.

This waste liquor *breaks down* the straw thoroughly, but also covers it with a thick, dark substance, the extract of straw dissolved in caustic soda, which makes the handling of it yet more objectionable, and also seems to prevent the fresh solution from acting as freely as it would on clean straw.

The use of waste liquor on fresh straw may in some cases be profitable to the mill by increasing the quantity of pulp made, but it is certainly not beneficial to the quality.

220. Manchester Paper Company.—One of the best articles of pure straw-paper has for many years been made by the Manchester Paper Manufacturing Company, near Poughkeepsie, N. Y., of which John Priestley & Co. are the agents.

The mill has lately undergone a thorough change, but had previously been worked in the following manner:

Rye-straw, delivered by the farmers from the surrounding country in nice, clean bundles, was exclusively used, and it may be stated here that this pure, raw material,

the produce of highly-cultivated farms, gives an advantage to this mill over many others.

The straw was first chopped into pieces of about $\frac{3}{4}$ inch in length by means of a cutter, and, while being fed to it, weeds and impurities were taken out by hand. The cut straw was freed from grain and dust in a grain-cleaner, and thence went to the *crushers*, consisting of a pair of short, heavy iron press-rolls, running with different speeds, and as close together as possible without touching each other. The hollow tubes and knots were thereby opened out, and made more accessible to the action of the liquor.

The straw thus cut, cleaned, and crushed, was filled into horizontal rotaries, with 60 gallons of a solution of caustic soda, testing from 3 to $3\frac{1}{2}$ degrees Baumé, for every 100 pounds of straw. These rotaries were walled in, heated by direct fire to a pressure of about 60 pounds above the atmosphere, and kept so for six to eight hours.

Two of these boilers discharged into a tub with drainer-bottom, of the kind previously described, wherein the liquor was washed out as completely as possible. From this tub the pulp was emptied into a stuff-chest serving as reservoir to a Kingsland engine, and any knots or bundles of fibre, which might not have been thoroughly reduced in the boiler, were brushed out or separated during its subsequent passage through the latter.

From this Kingsland engine the stuff was conducted into drainers, and remained there until dry enough to be taken out and furnished to an ordinary washing-engine. There it was washed again, bleached in the usual manner with a solution of chloride of lime, and emptied into a second set of drainers.

The bleached pulp was taken from the drainers, mixed with size, color, and clay in beating-engines, then passed through a second Kingsland engine, and run over a Fourdrinier paper-machine.

The paper made by this process was soft, clean, and white, and, although made of straw alone, found a ready market for book printing and other purposes at higher prices than were usually paid for straw-paper.

The production of the mill was never forced, and the proprietors stated that the operations were conducted more with a view to quality than to quantity.

Since the mill has been reconstructed, the company manufacture paper from rags, esparto, and straw. The esparto and straw are digested in the old rotaries, which are, however, not heated by direct fire. Superheated steam is introduced through one of the journals, and the boilers are not allowed to revolve continually, but are only occasionally turned around.

The owners of this mill state that they obtain a yield of nearly 50 per cent. of paper from straw, and of nearly 60 per cent. from esparto (and clay?—The Author).

The splendid condition of the straw, as compared with that used at other mills, may in a measure account for such an extraordinary result; but the proprietors attribute it in part to the great care with which their operations are conducted.

Everything is managed with a view to saving the fibres; the pulp in the wash-tub,

for instance, is not allowed to be stirred with paddles, or in any other way except by the water itself. No part of the raw material is lost, as it is all thoroughly reduced.

The author visited the Manchester Mill several years ago, and is indebted for additional information to Mr. John Priestley, whose sudden death, in December, 1872, must be considered a serious loss to the paper trade, as it undoubtedly is to his immediate friends.

221. Quantity of Soda Ash Required.—The author has made printing-paper from straw for many years; has steeped the straw in boiling water as well as in hot waste liquor, and then boiled it in horizontal rotaries with pressures ranging from 45 to 110 pounds, but has never been able to produce thereby a good article with less than 25 pounds of soda ash of 48 per cent. for 100 pounds of straw. In comparing notes with other paper-makers who have worked in a similar manner, he has found that wherever the information given was uninfluenced by the possession of patent rights, their experience was about the same.

The proportions recommended by Mellier may be modified by crowding larger quantities of straw into the boilers, by a preliminary treatment of it, and by the use of boilers of improved construction.

222. Yield of Straw.—It has been found by numerous analytical tests, that the different kinds of straw contain only from 46 to 50 per cent. of pure fibre or cellulose (see article 205). It must also be remembered that the same agents which dissolve the intercellulose are also destructive to the fibre if the limits of time, heat, or strength of liquor are overstepped, and it is practically impossible that this point should be reached to a nicety. It is more likely that, while some of the bundles of fibres or pieces of straw are yet covered with incrusting matters, other easier accessible ones may be perfectly free, and must necessarily suffer while the former are being cleared. Whenever the fibres are to be extracted from the straw in a perfectly pure state, it is, even with the most perfect treatment, unavoidable that a portion of the 46 to 50 per cent. should be decomposed, or, that some of the weaker cells should be detached and carried off mechanically. Every one of the operations following that of boiling—the washing, bleaching, and the formation of paper on the machine—are causes of further losses for straw as well as for rag-pulp.

It is the experience of many experienced manufacturers that, as a rule, not over 33 per cent., or about one-third of its weight in good white paper, can be obtained from straw in the rough condition in which it is received at most mills. If the straw is of extra good quality and unusually clean, the yield may be somewhat increased.

If it is considered that rags, which consist almost altogether of once bleached fibres, lose from about 20 to 40 per cent. while they are being manufactured into paper, it is only reasonable that the 46 to 50 per cent. of rough, unbleached straw-fibres should lose a similar proportion.

If an insufficient quantity of soda be used, or if the temperature be kept too low, or if not enough time be allowed for the operation, the yield may be a larger one; but instead of pure fibre, it will consist partly of those silicates and intercellular matters

which give to the straw the faculty of standing upright in the midst of storms, and while carrying a considerable weight. They also give to the paper the same qualities, making it harsh and brittle, though it may, through forced bleaching, have become perfectly white.

Reliable paper-makers have repeatedly stated that they obtain 50 per cent. of white paper from straw alone.

There are two methods by which this can be done: either by the production of paper of inferior quality, containing much of the intercellular matters, or by not counting the clay and size, which have been added in sufficient quantities to make up for the lost fibres.

B. *New Patented Processes.*

223. Principles for the Construction of Straw-Boilers.—The qualities which a perfect boiler for the digestion of straw should possess are:

That it can be well filled without much labor; that the liquor be introduced while the straw is packed in, the latter thus *broken down* and its bulk reduced.

That the straw shall be constantly brought in contact with different portions of the solution, without being subjected to any motion which may damage it by friction among its own parts or with the boiler.

That a high temperature can be applied and sustained without the use of fire on any part of the boiler which may come in direct contact with the straw.

That it can be emptied quickly and without much labor.

That it be simple, and easily kept in repair.

The difficulties experienced with horizontal revolving boilers have caused the invention of a large number of boilers of other constructions; but, although the author has endeavored during many years to acquaint himself with all the improvements made in this line, by his own experience as well as by personal investigation of the operations of other mills and of the patent-files at Washington, it is quite possible that there may be inventions of merit which have not come to his knowledge.

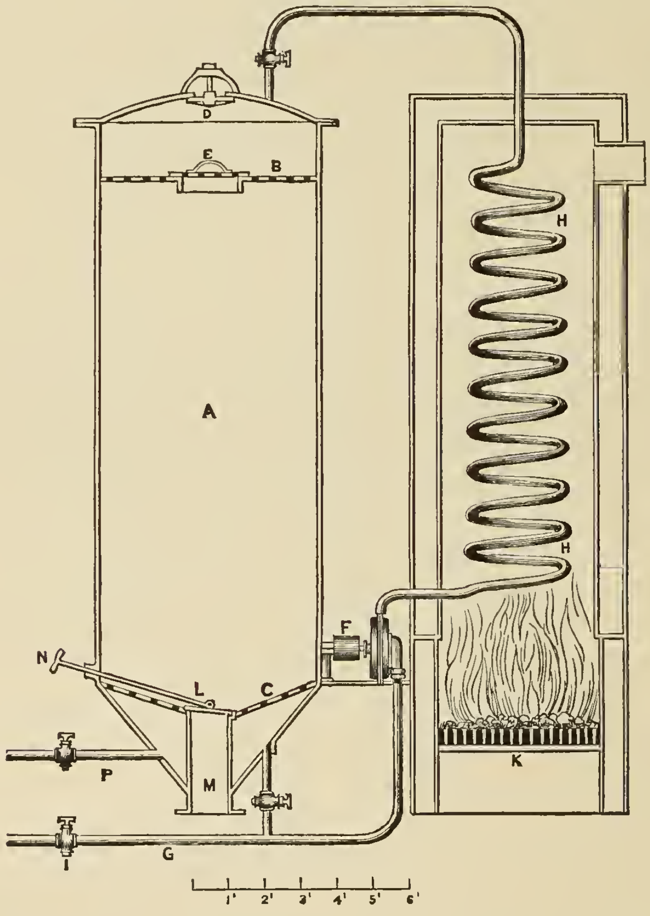
The following pages will contain descriptions of those improvements only which have either been practically successful or which present some novel features.

224. John Dixon's Boiler.—John Dixon received patents in 1864 for an upright boiler, which seems to answer all reasonable expectations. It is represented in section by the following, Fig. 119, and consists of a cylindrical boiler A, standing upright and immovable on its end, carried by flanges riveted to the shell in any desired place, and supported on solid framework or walls.

It is located so that the upper part projects a few feet above a floor, where the straw is stored; and a man standing there can easily open the manhole D, lift the cover E from a corresponding opening in the upper diaphragm B, and fill the boiler through them alternately with straw and caustic liquor. The straw, which has been previously cut, is supported by the lower funnel-shaped diaphragm C, and *broken down*

to such an extent while being packed in, that a boiler of 6 feet diameter and 15 feet height between diaphragms will hold from 4000 to 4500 pounds. A rotary pump F, fed from the liquor-tank through pipe G, forces the balance of the caustic solution through the coil H to the top of the boiler above the diaphragm B, and, after the apportioned quantity has been pumped in, the communication with the tank is cut off by closing the stop-cock I. The caustic solution percolates through the straw, collects under the diaphragm C, and returns through pipe G to the pump F, which forces it again through the coil and on top of the diaphragm B.

Fig. 119.



The coil H is made of extra heavy 2 inch wrought-iron pipe, placed in a brick furnace, and heated from the grate K. The steam which is thereby raised creates a pressure, which can be regulated by the fire, and observed on gauges and safety-valves connected with the upper part of the boiler.

Mr. Dixon recommends 60 pounds over-pressure; he sets two or more boilers close together, and fills one of them with wood, chopped into pieces of 1 inch in thickness. This wood is boiled with a solution of caustic soda of from 9 to 10 degrees

Baumé, which, after having served for it, is used for the digestion of straw in a second boiler.

He recommends the blowing out of the liquor from a boiler filled with (poplar) wood directly into one filled with straw; but experience at the Ashland Mills, Manayunk, Philadelphia, has shown that no good results can be obtained in this way. The operations are therefore conducted on the following plan:

A caustic solution is prepared from 1 pound of soda ash of 48 per cent. for every pound of paper obtained from wood, or—as a cord of wood furnishes from 800 to 1000 pounds of white paper—from 1000 pounds of soda ash for every cord of wood.

The wood having been digested with this solution, the latter is blown through the pipe P into a receiver, situated on the upper floor, and, after having been heated by the direct introduction of steam, a portion of it is drawn off and mixed with fresh liquor prepared for straw. Unless the liquor which has previously been used on wood is again well heated and mixed with a fresh solution, the straw, which is subsequently boiled with it, will furnish an imperfectly prepared pulp.

The waste liquor from one boiler of wood is, by this method, divided between two or three of straw; and we have been assured that 25 pounds of white paper from wood and 75 pounds from straw, or altogether 100 pounds of white paper, are thus obtained with the use of little more than 50 pounds of soda ash of 48 per cent., by this process of boiling.

In several other mills straw alone (no wood) is digested in Dixon boilers, and the caustic liquor used is then only of a strength indicated by $3\frac{1}{4}$ degrees of Baumé's hydrometer.

The time which is required with this boiler for one operation is about the same as with rotaries; but it is claimed that straw can be digested in it with less soda ash than in the latter; and, if we consider that the losses from friction produced by motion are avoided, and that the straw occupies less space, and can therefore be boiled with a smaller amount of solution, the statement may well be credited.

From 16 to 20 per cent. of 48 per cent. soda ash and 45 gallons of liquor are, according to the best information which we can obtain, used for 100 pounds of straw in Dixon's boiler, if good white paper is to be made.

The boiling being finished, the slide-valve L is opened from the outside by turning a screw and handle N, when the contents empty themselves through the channel M into a chest or tank below. The pulp is discharged with violence by the pressure of steam inside, and to prevent it from being splashed about, the receiving vessel must be well inclosed all around. The pulp emits also large quantities of steam, for which an outlet, in the form of a large pipe or stack on top of this chamber or receiver, is provided.

Simple as this process seems, it has its difficulties, and requires good management and supervision.

If the fire under the coil gives at any time too intense a degree of heat, the steam-pressure may rise suddenly, sometimes as high as to 120 or 140 pounds, and, instead of forcing the solution through the straw, press the latter into such a com-

pact body that percolation through it becomes impossible. This can be prevented to some extent by connecting the top with the bottom, outside of the boiler, by means of a one-inch pipe, so that the pressure at both ends and all through the cylinder must be always the same. A careful man only, who can manage the fire so that the pressure will remain uniform, should however be employed.

A pipe, connecting with a steam-boiler, enters below the diaphragm C, and is opened whenever the compact mass of straw requires to be loosened; it is also used before the circulation of the liquor is started, and facilitates percolation, as the steam penetrates through and raises the straw bodily.

The simplest of rotary pumps is the best for steady circulation. The Holly pump is used in several mills, but it has four stuffing-boxes, which are to be kept in order, and the pumping-cogs inside are liable to become coated, in the course of time, by the gummy extracts from the straw, and may give trouble. Centrifugal pumps, making 1000 to 1500 turns per minute, throw the solution constantly against the periphery, and thus keep it away from the stuffing-boxes. They are simple, have no parts which can be clogged, and seem to answer very well for this purpose.

Soapstone packing has been found to endure the action of caustic soda better than any other.

The liquor becoming saturated with the soluble part of the straw, and also carrying mechanically some fine fibres, sometimes deposits these substances through the action of the fire as a pasty mass on the inside of the coil-pipes, where they accumulate, so as to fill entirely some parts of the pipe and to stop the circulation. The pressure of the pump, hooks, and similar contrivances, have been found entirely inadequate to remove such obstructions.

Whenever they occur, the coil should be disconnected from the upper part of the boiler, as much water as possible forced into it by means of the pump, and its communication with the latter shut off by the closing of a stop-cock. Fire must then be started under the coil, and the water in it transformed into steam until the pressure is strong enough to force out the obstructions at the upper open end. An explosion, which is sometimes as loud as the report of a gun, accompanies the discharge, and gives an idea of the pressure which was required.

It seems that the circulation of a liquid through a stationary column of straw becomes more difficult as the latter is gradually transformed into pulp.

The Dixon boilers have, however, been in successful operation for over five years at the Inquirer Mills and the Ashland Mills at Manayunk, Philadelphia, and at several others.

225. William Ladd's Patent Boiler.—William F. Ladd, general manager of the American Wood-Paper Company, has received a patent, dated May 30th, 1871, for a horizontal rotary boiler, which can be turned end over end, on journals, attached to it in the middle of its length, so as to stand upright, while it is charged with straw through a man-hole in one of the heads; but we are not aware that such a boiler is anywhere in practical use.

226. Dr. Charles M. Cresson's Patent.—The table in article 205, which gives the composition of different kinds of straw, shows also the proportions of intercellular substances, which may be extracted by water. In order to obtain such an extract for experiments some straw may be boiled in water, when the latter will be transformed into an acid fluid, from which, on the addition of an alkali, a gelatine-like mass is precipitated. This sediment, although soluble in water, is evidently insoluble in alkaline liquids, and the conclusion suggests itself from this fact, that boiling in water should precede the treatment of straw with caustic soda in our mills, in order to remove it. Dr. Charles M. Cresson, of Philadelphia, who has been for many years chemical expert of the American Wood-Paper Company in several of their lawsuits, has made numerous experiments on this subject, and embodied the results in the following specification of his patent, dated July 11th, 1871:

"The object of the invention is to produce a fibrous mass from straw, which shall be capable of being felted and formed into sheets and suited for paper-making, and when desired to be of a white color, to be easily bleached; the production of such a pulp to be accomplished with the least expenditure of time, labor, fuel, alkali, and bleach, the process being capable of such modifications as will admit of the relative adaptation or proportioning of these expenditures, so as to suit the changes of the market value of each element, from time to time, and thus to secure the most economical results. The invention consists in the combined use of a water bath in an open vessel, or under pressure, together with boiling in caustic or carbonated alkaline solutions, either under pressure or in an open vessel, as hereinafter described; bleach to be used with the product when desired.

"By experiment I have ascertained that, by boiling straw in ordinary soft water, we can extract a certain amount of its substance, amounting in some instances to more than 70 per cent. of its weight, the amount depending upon the volume of water used, and upon the duration of the boiling, and the temperature to which the solution is subjected. The straw, when subjected to the treatment of boiling in a moderate amount of water and at not too high a temperature, loses its bright color and characteristic rigidity, and becomes changed into a soft and pliant material, which will easily split into filaments, but which will not, without further chemical treatment, be converted into suitable pulp, or easily whiten by the application of bleach, and is not fit to be formed into white paper. If this boiling in water is made at too high a temperature, the straw will be broken up into a fibrous mass of dark color, which cannot be converted into a pulp fit for white paper by means of subsequent treatment with a moderate percentage of alkali or bleach. I have also found that the matter extracted from straw by boiling in water has acid reactions, and that it will neutralize a considerable amount of alkali. I have also found that the acid solution produced is capable of dissolving portions of the intercellular matter of the straw, which are not so readily dissolved either in water or solutions of caustic or carbonated alkali. I have further found that, by treating straw with a proper amount of water for a longer time at a low temperature, or for a shorter time at a high temperature, we are enabled to produce a good pulp by boiling the resultant product in a solution containing a much less percentage of caustic or carbonated alkali than is necessary when the straw is treated only by caustic-alkali solutions, and at a lower temperature than by any other means known to me, and that the said pulp will whiten with less percentage of bleach than any pulp produced at similar temperatures, and by the use of an equal percentage of alkali. Furthermore, I have found that by the combined use of a water treatment at a high temperature, and the use of an alkaline bath of much less percentage of caustic alkali than is now employed, also at a high temperature, a pulp is produced from straw that will whiten with a less percentage of bleach than that produced by any process now known to me; and that by properly proportioning the amount of water used, and the pressure and the percentage of caustic or carbonated alkali used and the temperature, we can obtain from straw a greater percentage of pulp fit for making good white paper than can be obtained by any other process or processes that I have a knowledge of.

"I take any given amount of straw, and (after washing it and cutting it into short pieces, or not, at pleasure) place it in a boiler with from six to nine times its weight of water—say seventy to one hundred and ten gallons of water to one hundred pounds of straw—and boil it from two to ten hours in an open boiler, keeping up the supply of water as lost by evaporation, or from thirty minutes to three hours in a closed boiler, at any temperature that is convenient, say from zero to one hundred and fifty pounds per square inch. The temperature, and volume of water, and time of boiling, determine the amount of alkali and the temperature necessary for the second part of the process, and greatly influence the percentage of pulp obtainable. The less the amount of extractive matter, within the limits hereinafter indicated, removed by the water, the greater is the amount of alkali and temperature necessary to produce a pulp that will whiten with a given percentage of bleach. I do not limit myself to the exact amount of water, as herein expressed, in which the straw is to be boiled; for, in order to produce the most economical results, it is necessary to adapt it to the age and condition of the straw to be treated. In the operation with an open vessel, water enough should be used to remove from 12 to 20 per cent. of the substance of the straw. For the production of a finer pulp, and when the boiling in water is under pressure, the volume of water and temperature should be so proportioned as to remove from 20 to 40 per cent. of the substance of the straw. The volume of water to be employed, as before specified, I have found suitable for use with good dry wheat and rye straw from six to twelve months old, and from which the knots have not been removed. If the boiling in water is carried on in such a manner as to remove more than 45 per cent. of the substance of the straw, the percentage of the pulp obtained will be very much diminished, and without a corresponding useful diminution of the alkali necessary for the second part of the treatment, or of the bleach necessary to whiten the pulp. And if the boiling be carried on with such a volume of water, and at such a high temperature as to break up the structure of the straw and to reduce it to filaments or fibres, it will be found that the result cannot be easily converted into a pulp fit for white paper by subsequent treatment with alkali or bleach, or both combined. I find that the best results can be obtained by the employment of from 55 to 80 pounds to the square inch, as a 'high' pressure for either the first or second part of the treatment, and that the only advantage in using a higher pressure is to shorten the time of treatment necessary, and that, as a general rule, the use of such higher pressures entail a percentage of loss by the mechanical detachment and separation of the more minute vessels in the pulp, so that they pass off in the water employed to cleanse the pulp in subsequent stages of its preparation. I have found that by boiling straw in an open vessel for ten hours with nine times its weight of water, I could, by boiling the result in a solution of caustic soda (NaO), containing of caustic soda an amount equal to 14 per cent. of the weight of the straw, produce a pulp at 45 pounds pressure (about 300 degrees Fahrenheit) that would whiten with less than 20 per cent. of its weight of bleach; and that by boiling straw in seven times its weight of water, at a pressure of 100 to 120 pounds per square inch, for half an hour to an hour, and again boiling the result in a solution of caustic soda (NaO), containing of caustic soda an amount equal to 11 per cent. of the weight of the straw, for two hours, at a pressure of seventy pounds, I could produce a pulp that would whiten with less than 12 per cent. of its weight of bleach. The straw is best prepared by cutting into small pieces and washing it, although neither operation is absolutely necessary. It is then to be subjected to the process of boiling in water, as before described, either in an open vessel or under pressure; the water is then to be drawn off or blown off, and, while the material is still hot, the alkaline solution is to be run on, and the second part of the treatment gone on with.

"I have allowed the resultant material from the water boiled to become dry between the stages of the process, but it is much better not to do so. As soon as the material is sufficiently boiled in the alkaline solution, it can be treated by any preferred mode for disintegrating, screening, washing, and bleaching. By boiling straw in the larger volume of water and at a high pressure (over 55 pounds), we obtain a result which, if treated with a solution of caustic alkali containing of caustic soda (NaO) an amount equal to 10 or 12 per cent. of the original weight of straw, also at a high pressure, we obtain a moderate percentage of pulp, which will readily whiten with a small amount of bleach, and will make a soft and fine white paper. By boiling straw with about seven times its weight of water,

at a pressure of 60 to 80 pounds to the square inch, from thirty minutes to an hour, and blowing out the solution, and then boiling the resultant product in a solution of caustic alkali containing of caustic soda (NaO) an amount equal to 10 or 12 per cent. of the original weight of straw at a pressure of 45 to 50 pounds to the square inch, we obtain a larger percentage of pulp, and one that will whiten readily with a moderate amount of bleach.

"To produce a pulp from which an ordinary paper can be made—one not required to be of a pure white color—it is only necessary to make the boiling in water in a large volume of water, and in an open vessel, and to boil the result in a caustic alkaline solution, at any pressure above atmospheric pressure (the less the pressure the greater percentage of pulp obtained), or to boil the straw in a smaller volume of water, at any pressure above atmospheric pressure (212 degrees Fahrenheit), and then to boil the result in a solution of caustic alkali, in an open vessel.

"To produce a pulp that will make a fine and soft white paper from straw alone requires that both boilings be made under pressure, and if both be made at a pressure giving a temperature above 310 degrees Fahrenheit, a minimum of alkali and bleach will be required, but, at temperatures above 310 degrees Fahrenheit, the yield of pulp diminishes considerably, and such temperatures should only be used when great economy of time and of bleach is necessary, and a very soft, white paper is desired.

"I find it useful to run or blow the acid liquor (obtained by boiling the straw in water) through the straw that is about to be subjected to the process of boiling in water, and that it is useful, after having blown off the acid liquor, to blow or run the waste alkaline solution over the result (obtained from the straw by boiling it in water), to insure the removal or neutralization of the acid extract, which would otherwise neutralize and render inefficient a portion of the alkali employed in the second part of the process. The waste solution retains sufficient alkaline properties to neutralize the acid solutions remaining in the interstices of the material about to be subjected to a boiling in an alkaline solution. In the treatment in an open vessel the boiling may be effected by means of a fire beneath it, or by steam-pipes or jackets, or by jets of steam blown into or through the liquid in which the straw or material has been immersed."

We are not aware that this process of treating the straw with hot water in the manner described, before it is boiled with caustic soda, has ever been carried out on a large scale for a sufficient length of time to warrant any valuable practical conclusions regarding it.

227. Morris L. Keen's Process and Patents.—Mr. Morris L. Keen, who has been for many years connected with the American Wood-Paper Company, has received several patents for a process of making wood and straw pulp, by which everything that can be removed from wood or straw, by means of water and steam, is first extracted before caustic lye is used. This is, though done in a different way, substantially what Dr. Cresson aims at.

Mr. Keen's process, however, has been in practical operation at Messrs. Israel D. Condit & Co.'s mill, at Shawaugunk, N. Y., and has furnished some very fine pulp. The mill was destroyed by fire September 20th, 1872, but we understand that it is being rebuilt, and is to be again supplied with Mr. Keen's boilers.

The description of the process given in the patent dated October 18th, 1870, reads as follows:

"I will describe the invention as applied to the manufacture of pulp from poplar or analogous soft woods.

"After wood has been reduced to fine chips by any suitable cutter or machine, the chips or

shavings are put in a close, strong boiler, one of an upright form preferred, fitted with a perforated false bottom inside, so that the stock under treatment can be drained off by means of a cock in the bottom of the boiler, communicating with space under the false bottom.

"A discharge-valve also is fitted to a passage through both bottoms, communicating with the interior of the boiler, so that the stock of pulp, when finished, can be discharged or blown out under pressure into a suitable receiver or tank for said purpose.

"The boiler is also provided with a top screen or perforated diaphragm, fitted across the inside of the top of the boiler, allowing a steam-space above the screen.

"The boiler is charged either through a manhole above or below the screen, a portion of the screen being removed in the former case to admit of charge.

"After the boiler is charged with the wood and the manhole secured, steam is admitted to the boiler from a separate generator, by means of pipes at the top of the boiler, and manipulated at pleasure.

"After steaming the stock for thirty minutes, more or less, according to the fineness of the shavings or chips, at a temperature of from 300 to 400 degrees Fahrenheit, the drain-cock is opened at the bottom, and the condensed water drawn off. Hot water is now injected, at a temperature of from 300 to 400 degrees Fahrenheit, above the screen into the steam-space, and percolates freely through the stock under treatment, and washes out the interstitial matter.

"By alternating the treatment from steam to water and water to steam every five or ten minutes, for thirty minutes or more, according to the previous condition and kind of stock under treatment, it will be found that at least 40 to 50 per cent. of the interstitial matter of straw or dry wood will have been removed, and 50 to 60 per cent. of green wood will have been removed.

"All dry stock may be steeped with advantage in hot or cold water, as a preliminary process.

"The charge is now ready for the alkaline treatment, but if thought desirable it can be drawn from the boiler and more thoroughly washed, and more of the interstitial matter thus removed, or it can, in this stage, be made into common brown paper.

"The stock, as left in the boiler after the steam and hot-water percolation, may be transferred, with or without extra washing, to another boiler, or retained in or returned to the same in which it was originally steamed, and subjected to the action of alkali, either in a carbonate or caustic form, in solutions of the strengths and temperatures described below, and, as most of the interstitial matter has been previously removed, it is easily reduced to a pulp, with about 33 per cent. of the alkali now used by any other of the present approved manufacture of wood or straw-paper; that is to say, a good pulp can be produced by boiling the stock of wood or straw, &c., previously cleaned of much of the interstitial matter by the steaming and hot water process, in solutions of caustic alkali of 20 to 25 per cent. of wood-pulp produced, and in 8 or 10 per cent. of caustic alkali to straw-pulp produced.

"The strength of alkali preferred for wood is about 10 to 12 degrees Baumé; that for straw, 6 to 8 degrees; though much weaker solutions will answer nearly as well.

"The alkali is first charged for wood, at the rate of 1 gallon at 8 degrees Baumé to every pound of wood under treatment, and for straw, 1 gallon at 5 degrees Baumé to every pound of straw under treatment, and the heat raised in the boiler to a temperature indicated by 10 to 30 pounds pressure on the steam-gauge.

"I have made good pulp at 10 pounds pressure, and have also pulped the wood, straw, and similar materials, having been previously acted on, in the manner described, by steam and hot water, in open vessels, without any pressure whatever. It is, however, preferred to treat the stock, under the pressure of 30 pounds, in a close boiler, in caustic alkali of strength described, as the action desired is obtained under the heat indicated by that pressure in a shorter time than at a lower temperature.

"With most stock this should be continued about one hour. I do not, however, confine myself to the pressures or temperatures named, as higher pressure can be used to nearly equal advantage, and lower steaming will answer the purpose, but those named seem to be about the best for commercial use.

"It is important that no considerable quantity of steam be allowed to condense in the boiler at

this stage, as it would weaken the strength of the solution. I therefore prefer to maintain the temperature by the admission of steam, at a proper pressure, to an exterior jacket alone, or to a jacket and coils, or other provisions for heating the interior.

"The construction of the boiler should, in this respect, depend much on its size. If the boiler is large, ample provision should be made for introducing heating-surfaces in its interior. If small, the heat may be maintained from the exterior sufficiently.

"The alkali is now drawn off at the drain-cock in the bottom of the boiler, measure for measure; that is, the stock is now freed by percolation, and a sudden injection of steam, in the top of the boiler, over the stock.

"The stock is now steamed again under high pressure, indicated by from 70 to 200 pounds by steam-gauge, and hot water also injected at the temperatures corresponding to those pressures, to which treatment and which temperature the charge is kept fifteen or twenty minutes, and then drawn out or blown out into a proper receiving-tank, drained, and washed by percolation, and assumes the condition of good gray pulp, ready for bleaching by any of the ordinary known methods.

"The stock, in a cleansed state, at this stage of process, prior to its discharge from the boiler, may be again subjected to percolation by steam and hot water, so as to remove a great part of the extraneous matter liberated by the last steaming and hot-water treatment, and a solution of weak chloride of soda, less than 1 degree Baumé, admitted to the boiler, which is raised to a temperature of 300 degrees for ten or fifteen minutes, and the stock then blown out. This greatly improves the color of the stock.

"The alkali drained off from the boiler is reserved and replenished for future use; that is, one-sixth of its original quantity is discarded and set aside for the recovery-furnace, and that quantity, by measure, at a strength of from 10 to 12 degrees Baumé for wood, and of the straw-liquor the same quantity, one-sixth, is discarded, and a fresh charge or amount of one-sixth new liquor, or caustic alkali, is added, at a strength of 6 to 8 degrees Baumé, or such strength as to maintain the proper strength in the liquor. And this order is preserved of discarding one-sixth of alkali used in every boiling, and replacing the same with new alkali.

"The waste or discarded alkali can be recovered in suitable evaporating furnaces, at a loss of from 10 to 15 per cent. for recovery of said waste.

"The boiler, in the alkaline treatment, may be heated by an auxiliary coil, through which the large amount of alkali freely circulates, and in which the bulk is retained during the discharge of waste alkali, or any other desirable method to economize time and heat.

"The first steaming and hot-water treatment may be dispensed with, and good pulp produced from straw and very finely reduced woods of non-resinous character, by simply boiling the same in solutions of caustic alkali of strength indicated, with the subsequent percolations and steaming; but the renewal of liquor at subsequent boilings must, in such case, be increased from two to threefold, as the interstitial matter not removed by first steam and hot-water process has to be overcome by extra amount of caustic alkali.

"Although I esteem the above process entire, and all the several novel parts thereof, more particularly valuable in its application to wood and straw, I believe it may be used with much benefit on various other, and, in short, nearly or quite all paper material. The first portion of it, to wit, the extraction of most of the interstitial matter by the alternate steam and hot-water treatment at high temperatures, I propose particularly to employ in preparing paper-stock from hemp, flax, and tow of either or both.

"I can use carbonate of soda, or other alkaline carbonates, instead of caustic alkalies."

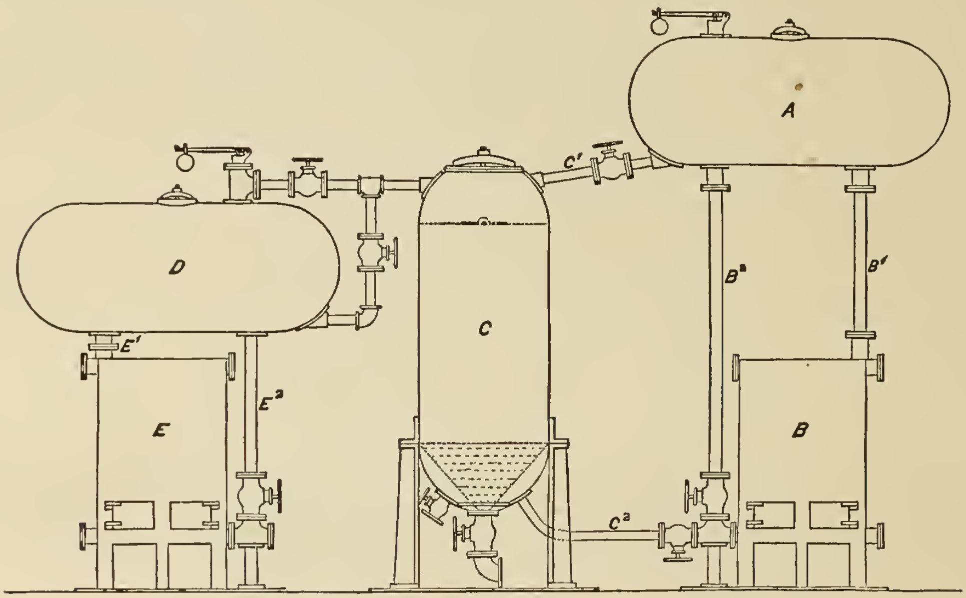
On May 2d, 1871, followed the patent for an apparatus by which this process was to have been put in operation. It is represented by Fig. 120 and the following description, both copied from the letters-patent:

"My invention is adapted to the treatment of wood, straw, cane, esparto grass, flax, flax tow, hemp, hemp tow, jute, jute tow, manilla grass or rope, manilla tow, and all analogous materials or vegetable substances for the manufacture of paper-stock or pulp therefrom.

"It has long been common to treat some or all of these materials with alkaline solutions.

"My invention constitutes a novel and convenient apparatus for applying the alkali and maintaining the temperature in the alkaline solution preparatory to and during the treatment of the paper-stock with said solutions.

Fig. 120.



"I heat the alkaline fluid by a coil, through which the alkali circulates, to which coil is attached, in an elevated position, a large alkali-reservoir or charging-drum A (Fig. 120). A fire being maintained in a furnace, in connection with the coil, the alkali is heated at each passage through the coil.

"The coil is inclosed in a casing B, and may be of any ordinary construction. The alkali circulates between the coil B and the charging-drum A, and thus maintains any desired temperature in the charging-drum for any period.

"Under these conditions, when the stock-boiler C is charged with the alkali, it is done at the desired temperature, which temperature is maintained in stock-boiler C by circulation of the alkali through the coil.

"I take care to make the charging-drum A of such capacity, and to supply such a quantity of alkali thereto, that there shall remain sufficient alkali in the charging-drum A after the stock-boiler has been filled to maintain a thorough circulation of alkali through the coil B, charging-drum A, pipe C^1, stock-boiler C, and pipe C^2 into coil B, during which time the valve in pipe B^2 may be closed, the other valves all open.

"After the paper-stock boiler C has been sufficiently treated, it is intended that five-sixths of the alkali in use during this process shall be returned to the alkali charging-drum A. This may be conveniently effected by steam admitted from the steam hot-water drum D, which is similarly heated by coil E, with similar circulating-pipes E^1 E^2.

"It is intended that one-sixth new alkali-liquor shall be added to it to form a fresh charge for the next operation.

"If weak alkaline solutions are employed, the entire charge of alkali used may be discarded after each treatment, and a fresh charge of the solution admitted to the charging-drum from a suitable reser-

voir or other source, not represented; but in either case the temperature is maintained in the charging-drum by means of the coil and connections, arranged as represented.

"It will be understood that the alkali is conducted from the charging-drum A to the stock-boiler C through pipe C^1; and when the steam is admitted to drive back the alkali, the valve in the pipe C^1 is closed, and the valve in the lower pipe C^2 being opened, the steam from the hot-water boiler D, being admitted to the top of the pulp-boiler C, presses downward on the alkali contained in the interstices of the pulp and forces it down, through the strainer at the bottom and through the pipe C^2, into the heating-coil B and pipes B^1 and B^2, into alkali-charging drum A, to be there retained while the pulp is removed and all is made ready for the treatment of a new charge."

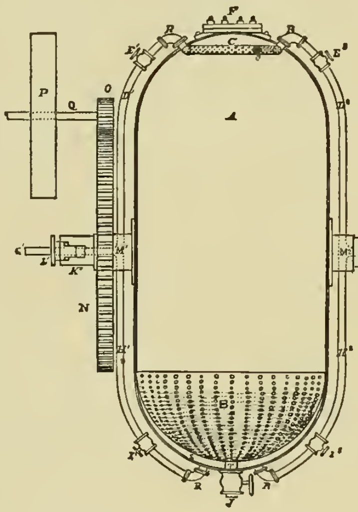
An improved boiler for the same process was patented by Mr. Keen, July 25th, 1871. It is represented by Fig. 121 and the following description, both copied from the letters-patent:

"The boiler is made strong and capable of being worked at any desirable pressure to accomplish the object of thorough cooking or disintegration, and may be termed an upright rotary boiler revolving on its short axis, end over end.

"The following is a description of what I consider the best means of carrying out the invention:

"The drawing (Fig. 121) forms a part of this specification, and represents a longitudinal section. Referring thereto, A is the general interior of boiler; B a bowl-screen or perforated false internal bottom, fitted securely inside of one end of boiler, and forms a draining-screen when the boiler is in a vertical position. C is a ring of pipe, perforated with small holes, and forms a shower-pipe inside the upper end of boiler, or manhole end, when the boiler is set in vertical position. Said shower-pipe is secured to inside of boiler by T-outlets, communicating through the bends R to pipes D^1 and D^2, and passages M^1 and M^2 through the trunnions K^1 and K^2. E^1 and E^2 are screw-valves commanding the communication through the pipes D^1 and D^2. F is the manhole bonnet or manhead of boiler. G^1 and G^2 are stationary inlet and outlet-pipes connected steam-tight to the stuffing-boxes L^1 and L^2 in the trunnions. H^1 and H^2 are pipes connecting between passage-ways M^1 and M^2 and the lower end, or that end of the boiler opposite to the manhead F. They are connected by bends R and R, and communicate with the space S under the false bottom B. I^1 and I^2 are valves in pipes H^1 and H^2. J is a

Fig. 121.



large blow-off or pulp-discharge valve connecting with inside of boiler through the short pipe T, which forms a passage through both the outside shell of boiler and the screen B. N is a large gear-wheel fixed on one trunnion, to which power is communicated by pinion O to revolve the boiler A. P is a pulley on counter-shaft Q, driven by any convenient power, not represented.

"The boiler A is charged with materials for paper-stock, and is treated with steam, water, or liquid chemicals, gases, or air admitted to or forced in the boiler through the trunnion-passages by pipes G^1 and G^2, leading thereto, and the pipes D^1 and D^2, and H^1 and H^2, separately or together. This may be done either while the boiler is revolving or standing still. It will be seen by the arrangement of pipes and valves that the stock can be subjected to treatment through shower-pipe, while the boiler is in a vertical position, through the trunnion K^2, by opening the valve E^2 communicating with the shower-pipe, while the bottom-valve I^1 is opened to passage through the opposite trunnion K^1, and the

waste liquids or washing discharged through it. By the arrangement of pipes and valves a great variety of manipulations of stock can be practiced, either in the upright or revolving condition of the boiler. The boiler can be discharged under pressure while in a vertical position by opening the large valve J, communicating with inside of boiler; or the steam can be blown out through the shower-pipe C, valve E^1, pipe D^1, trunnion K^1, and outlet-pipe G^1, after which the manhead F may be opened and the contents discharged while the boiler is reversed. The discharge-pipe leading, as shown, from the extreme bottom of the concave or dish-like perforated basin or strainer B, allows me to discharge the pulp completely and rapidly, by the force of the steam when desired. The double connection D^1 D^2 H^1 H^2 allows the current to be reversed momentarily at intervals to clear the strainer. The elongated form of my boiler induces a marked difference in the effect as distinguished from a spherical boiler similarly revolved. When, as usual, the boiler is only partly filled, the contents tumble, gather together, and tumble again; while in a spherical boiler there is no possible tumbling, but only a rubbing around on the spherical recessed interior. The annular form and arrangement of the sprinkler C, extending in a ring around the seat of the manhead F, keeps it out of the way of the ready access, which is so highly important, through the manhead, and yet gives an effectual distribution of the water equally on all sides of the manhole and over the whole mass of the pulp."

The apparatus which was at work in Messrs. T. D. Condit & Co.'s mill is the one represented by Fig. 120, but the revolving boiler (Fig. 121) was put in the place of the stationary one C of Fig. 120.

It had not been working very long, when it was found that the acid extracts, made from straw by means of hot water and steam, dissolved the iron of the digesting-boiler, and prevented the production of white pulp. This experience, as well as the means by which this unexpected difficulty was to be overcome, and the solution of the iron of the boiler prevented, are described in a patent dated October 3d, 1871, from which the following lines and Fig. 122 are copied.

"The shavings, chips, or cuttings of wood, plants, or paper-stock material are placed in a strong, close boiler, preferably a rotary boiler, revolving on its short axis, end over end, of form as described in my patent of July 25th, 1871, No. 117,427. I have discovered that treatment of these materials with steam and water, without alkali, as described in previous patents issued to me, is liable to develop acids, which attack the iron of the boiler, and injure both it and the paper-stock. The iron chemically dissolved from the interior of the boiler, becoming fixed in the paper-stock by the subsequent use of alkalies, leaves the paper-stock stained or dyed.

"My present invention consists in so modifying the treatment as to avoid this evil. I have satisfied myself that the preparation of crude paper-stock should not be made in an iron boiler with pure water or steam, if said stock is intended to be subsequently treated for white paper, unless some provision is made to preserve the boiler from corrosion and the stock from the impregnation of iron. The more perfect the disintegration and pulping of crude materials and removal of interstitial matter by pure water or steam, the more porous and spongy the pulp becomes, and the greater becomes the necessity for guarding against its impregnation and stain from iron.

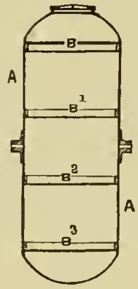
"My first mode of attaining this end is by electrical or galvanic means, which may be availed of in a cheap and convenient form for practical and permanent use. I find that the iron of the boiler may be electrically so conditioned as to prevent the action of acetic acid or pyroligneous acids, tannic acids or any other acids or acidulated extracts or spirits liberated during the treatment of paper-stock. Zinc, or zinc and tin, or other positive metals, may be introduced in the form of rings encircling the interior of the boiler at each end and at one or more intermediate points. I prefer to use it in the manner herein set forth and illustrated in the drawing, Fig. 122, hereto attached.

"A represents the boiler; B B[1] B[2] B[3], the rings of positive electric composition, shown by cross-sectional view.

"Other methods of electrical preservation of iron boilers from action of acids named, and the preservation of paper-stock or pulp from impregnation or iron stain by said electrical protection of iron may answer nearly as well. Iron boilers so conditioned I propose in the remainder of the specification to term electrically protected.

"Other means are available for working of my invention, which may be termed mechanical. One of the cheapest methods of mechanical protection is by plating the interior of the boiler with tin or any metal not liable to be affected by the acids generated in the process of producing paper-stock from crude materials. This is not, in my view, as reliable as the other mode, because of the liability of small portions of the surface of the iron to become exposed and induce mischief. I have not experimented with this plan, nor with an obviously available substitute—a boiler entirely of copper or other non-corrodible metal—but believe that my improvement in this treatment may be realized by these means, though in a less desirable manner. Either of these plans preserves the boiler from destruction by acids, and leaves the paper-stock or pulp in a pure condition, free from iron stains or rust, and in the best condition for future treatment with alkali and bleach to produce a pure white paper-stock at the lowest cost, and can be cheaply treated subsequently for white paper-stock or pulp by any of the present or other suitable methods. There are marked advantages attending the pulping or partial pulping of crude paper-stock without alkalies, but the considerable time of treatment required, either at low or high temperature, to remove the interstitial matter to produce the best pulp affords a prolonged time for acid action on the boiler, and a thorough charging of the pores of the pulp with tannate or acetate of iron, which cannot easily be washed out prior to the alkaline treatment made subsequently. The stock or pulp so saturated with tannate or acetate of iron is stained by the precipitation of the iron in the stock during its subsequent treatment with alkali, and is most difficult to remove from the pulp. It entails a tedious scouring and washing process to even partially effect it, and is then attended with serious injury to the stock. In a word, no crude materials or plants, intended for white paper-stock or pulp, should be treated by pure water or steam in an iron boiler, without provisions alluded to in this specification.

Fig. 122.



"I have found that with the provisions alluded to, which I have termed electrically-protected boiler, or with a boiler internally plated or coated, or composed of metal or material not affected by acids liberated in the treatment of paper-stock by hot water, or steam, or vapor, a good, crude paper-stock or pulp can be produced by treatment in a close vessel, with steam and water, from straw, cane, shavings of wood, flax tow, hemp tow, manilla hemp, jute, and all crude materials adapted for paper-stock. The stock under treatment should be thoroughly saturated with water. To obtain the best results, during the boiling and steaming all the interstitial matter liberated by this treatment may be washed out by percolation in a vertical boiler, or blown out at bottom of boiler, or the material may be dumped out, and squeezed or washed out prior to boiling said pulp in alkali. If the above treatment is made in the manner herein described and in the apparatus set forth, forty to sixty per cent. of the interstitial matter may be removed prior to the alkaline treatment, and only 8 to 10 per cent. caustic alkali in solution to 100 pounds raw material will be required for the production of a pure gray pulp that may be readily and cheaply bleached.

"The time and temperature necessary for the alkaline treatment depend on the stock under treatment, and will vary from thirty minutes to five hours, and from 212 to 380 degrees Fahrenheit, green, succulent stock being easily reduced, while the dry and seasoned materials require more time and increased temperature."

The owners of the patent admit that this *electrical protection* does not prevent the iron of the boiler from being dissolved by the acid extract, and that chemicals must be used with the water.

We have been informed by parties who have seen the process in operation that waste alkaline liquor, which has previously been used to digest a lot of raw material, such as straw, wood, or esparto, is the chemical alluded to. We believe that such is the case, and have no doubt that the presence of this or any other alkali will prevent the solution of iron, because the acids cannot be extracted with alkaline liquids.

It seems hereby fairly established that the extraction of their soluble parts from wood or straw, by means of water and steam in nude iron boilers, is impracticable.

We have seen samples of splendid white pulp, which had been made from straw and esparto by this process, as stated to us, with about one-half of the quantity of soda recommended by Mellier, and with about 14 pounds of bleaching-powders for 100 pounds of paper. Fifty pounds of white paper from 100 pounds of straw was stated to be the usual yield. An opportunity of verifying these statements by an inspection of the operations at the mill, although solicited, was not granted to us.

Mr. Keen has lately taken out another patent, dated July 9th, 1872, consisting principally of a stationary upright boiler, which, as we are informed, is not yet in practical operation. It is described in the letters-patent by the following Figs. 123, 124, 125, and specification:

"Specification describing certain Improvements in Apparatus and Process for producing Paper-Pulp and Paper-Stock, invented by Morris L. Keen, of Jersey City, Hudson County, New Jersey.

"The invention is applicable to the preparation of crude and fine paper-stock, and pulp from chips or shavings of wood, cane, and all analogous materials.

"The following is a detailed description of what I consider the best means of carrying out the invention.

"The boiler is of an upright form, made of iron, and electrically protected from action of interstitial matter liberated from crude materials for paper-stock during the treatment of the same in the boiler, and at the same time preserving the stock from iron stain, as set forth in my patent of October 3d, 1871, No. 119,465.

"The drawing attached to this specification shows fully the form of the boiler, and the mechanical appliances connected therewith.

"Fig. 123 is a vertical section through the entire work at and near the top and bottom of the boiler. Fig. 124 is a central section, and Fig. 125 a view from below, showing one of the important details on a large scale.

"Similar letters of reference indicate like parts in all the figures.

"The boiler A is preferably about 5 feet in diameter and 16 feet high, domed at top and bottom, strong enough to stand a working-pressure of 200 pounds to the square inch. B represents the charging-hole or manhead at the top of the boiler. J is a discharge-valve, where the pulp is blown out when ready. C is the conical strainer or false bottom, which acts as a funnel to guide the stock in its passage through the devil D^1, and as a strainer for admitting the free circulation of fluid material, at convenience, during any stage of the treatment, and for passage of all waste and washing fluid materials, when required, said fluids passing out through valve I. It also serves for the free admission of upward currents of steam or fluids forced in through valve and pipe H by the pipe F^2, when the valves G^2 and V are closed. U is an annular pipe ring inserted inside of the boiler near its top, and perforated with small holes to act as a shower-pipe for admission of steam or fluids for washing and treating the stock at different stages of the process. Said steam and fluids are forced in through outside pipe U^1, communicating with and forming part of the same. D^2 is a centrifugal disintegrating rubber, with ridges d^2 on its upper face (Fig. 124), and with suction-screw propelling-blades inserted inside of the

bottom of same to draw and force the materials under treatment with the fluid matter up the hollow shaft to near the top of the boiler. I is a drain-cock or valve communicating with the space under the false bottom C to drain off the interstitial and wash-water when required; D^1, a conical devil or hog, with centrifugal rubber disintegrator D^2 attached, firmly mounted on the end of hollow driving-shaft N^1, on the inside of bottom of boiler, which may be driven in any convenient way. N^1 is a spew-pipe shaft on which the conical devil is set. Said hollow shaft has outlets at T, through which a complete circulation of fluids or pulpy materials is passed, as they are forced up through the shaft by inside steam-injection pipe F', after passing through the conical screen C, some of the fluid matter being passed downward and outward through the valve H; thence down further and inward through pipe E, while the pulpy matter is delivered through the conical devil D^1, as marked by arrows. The whole is then passed up, under, and through the hollow interior of the disintegrating rubber D^2 by propeller-screw inside of same into the hollow shaft N', to be spewed out at the top through the nozzles T T, and

Fig. 123.

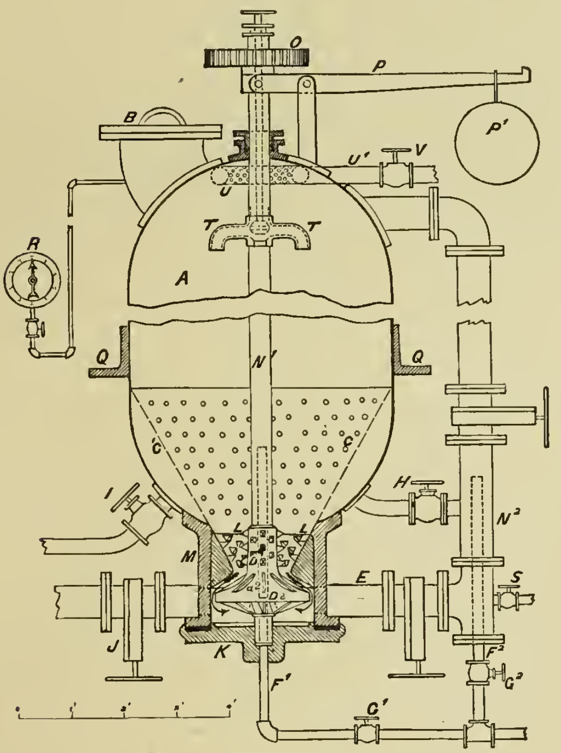
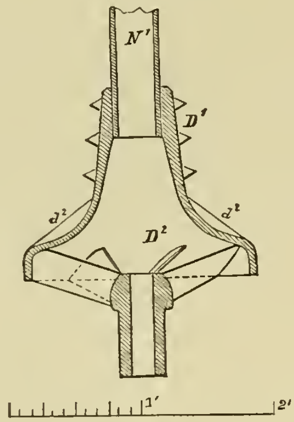


Fig. 124.



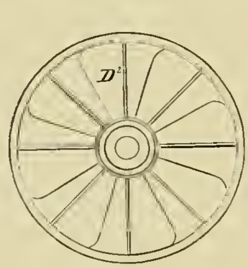


Fig. 125.

the round of operations repeated. During different stages of the process this operation is varied. G^1 and G^2 and V are stop-valves that may be closed at the time of discharging the boiler of its pulp through the valve J, or manipulated to assist in said discharge. H is a valve opening passage through pipe E from under false bottom to space under D^2 in case M, to admit of the free circulation of fluid matter in the early stages of digesting the crude material; S, a sample-cock to test the condition of stock at different stages of process. O is a gear-wheel to drive the shaft N^1; F^1 and F^2, steam-injection pipes to create a current of fluid and pulpy matter, and heat the same in its passage. As all the pulpy matter is brought in direct contact with the live steam in its passage through either the hollow pipe-shaft N^1, or the outside pipe N^2, it is thoroughly cooked and digested. M is the external case of conical devil and its adjuncts. K is the bottom cap and step of shaft N^1. L is the conical cup-section or shell of devil, commonly called the cup or hopper. P is a lever by which the devil, and especially its

attached centrifugal disintegrator D^2, is adjusted to its work, and raised and lowered in its work by changing the position of the weight P'. It is self-acting, to yield and admit of the passage of any hard substances that might choke or injure the devil, or the rubber, or disintegrator. R is a steam-gange, to indicate the pressure and temperature during the process. Q are brackets, to support the boiler in setting the same.

"The especial object of this invention is the treatment of crude paper-stock materials, and the reduction of the same to a pulp with water, or a weak alkaline solvent, or other eqnivalent solvent, as set forth in my patent, dated October 3d, 1871, No. 119,464, thereby enabling by subsequent treatment, as washing, the removal of the gummy and acid interstitial matter to any desirable point as to its destined use in the manufacture of papers of fine or coarse qualities. If the stoek is intended for coarse papers, the most of the interstitial matter may be retained and coagulated, as set forth in one of my former patents. If intended for white paper, the stock may be thoroughly washed in the boiler prior to its subsequent treatment in a solution of caustic alkali of given strength and quantities, and at such temperature and for such time as fully specified for different kinds of materials, all of which are fully set forth in former patents issned to me. The stock or pulp can now be discharged by blowing the same ont of a blow-cock or discharge-valve, as mentioned, fixed in the bottom of boiler, or the stock may be blown out after the first treatment described, for the liberation of and removal of the interstitial matter. The crude pulp can afterward be washed by any snitable apparatus or means, and thoroughly prepared and cleansed for the second treatment of boiling in a solution of caustic alkali of such strength and quantity, and at such temperatnre for such time as the kind of stock under treatment reqnires for the production of any desired quality of paper-stock to be made, either into fine grades of unbleached or bleached papers. For this last-named treatment in a caustic alkaline solution, I prefer to nse my patent boiler revolving on its short axis, as set forth in my patent issued Jnly 25th, 1871, No. 117,427."

Considering that perfectly good straw-paper has been and is made by one single operation of boiling in caustic soda and subsequent washing and bleaching, it seems that the previous treatment with hot water is not indispensable, and we must suppose that the substances which Mr. M. L. Keen and Dr. Charles M. Cresson wish to extract before the treatment with alkali, have heretofore been eliminated by the subsequent washing of the boiled pulp.

It is, however, probable and natural that less soda should be required for the extraction of the fibres from straw, which have already lost a part of their foreign matters by previous boiling with water, than is necessary for the unprepared fresh material.

Two separate boiling operations, instead of one, must be carried on for this purpose, and unfortunately in two different boilers, one of which must be constructed of some other material than iron, or both operations may be carried on in one boiler, if it is constructed of a material which is able to withstand the action of light acids as well as of strong alkalies.

Provided that the attempts to reduce the necessary quantity of soda by these means should be successful, it remains to be seen whether the additional machinery, labor, and fuel required therefor would not lead to an additional expense equal to the saving in soda.

228. Washing and Bleaching.—The operation of washing, following the different methods of digestion or boiling, described in the foregoing lines, is carried on in the

same manner as for Mellier's and similar systems, and has been discussed under that head. Washing-engines and wet-machines are used for this purpose in nearly all modern mills.

All that has been said about bleaching rags might be repeated here, as straw is treated upon the same principles, and only requires a larger proportion of material,—from 15 to 25 pounds of bleaching powders and a corresponding quantity of sulphuric acid being used for every 100 pounds of paper made from straw alone.

For paper which has been boiled with insufficient quantities of soda, a larger proportion of bleach-solution is necessary. It may be given as a rule that, everything else being equal, that which is saved by the reduction of soda ash below a certain limit, or to less than the quantity which is necessary to dissolve the incrusting matters, is lost by the increased use of bleaching powders and the poorer quality of the paper.

Several inventors have tried to reduce the quantity of soda and the temperature used for boiling, and to make up for imperfect digestion by more energetic bleaching. There is no doubt that straw-pulp prepared with comparatively small quantities of soda, can be made white by forced bleaching, but the incrusting matters are then not thoroughly removed, and give to the paper the characteristic brittleness and stiffness which remind us of its origin.

A surplus of free chlorine decomposes the cellulose by uniting with its hydrogen and perhaps withdrawing it while the carbon remains; the fibres thus become *carbonized* or burnt, and will not form as good a paper as might be obtained at the same cost by a better digestion of the raw material.

In some mills steam is admitted to the pulp while it is bleached in the engine, and a slight elevation of the temperature certainly assists the chemical action.

In many cases it will be found that the difficulty experienced in bleaching straw-pulp is caused by the presence of alkali, which has been neither neutralized by sulphuric acid, nor thoroughly washed out.

The bleach solution which escapes from the drainers is, if sulphuric acid has been used, loaded with hydrochloric acid (see articles 34 to 40), and it is therefore not advisable to let it remain for a long time in contact with the pulp, nor to use it for the preparation of fresh solutions. It is best, not only to let it drain off as quickly as possible, but also to empty the bleacher with a large quantity of water, and thus to soak and wash the white pulp immediately in the drainers. Hydrochloric acid turns the pulp a yellow gray; we have seen stuff, which had been emptied from the bleacher as white as snow, turn yellow-gray in the drainers, because the hydrochloric acid had not been washed out with clear water.

The chlorine, remaining in the liquid which escapes from the drainers, may be used up by being added directly to the gray pulp in the washing-engine as a preliminary bleacher, and then washed out again. The more the waste bleach-liquor is manipulated and exposed to the action of the air, the sooner will all its chlorine be

transformed into hydrochloric acid; if it is to be used at all, it should be done as quickly as possible.

229. Bleaching in Rotaries.—In some mills rotary boilers, similar to the one represented by Figs. 16 and 17, are used instead of bleaching-engines. The straw-pulp, bleach-solution, and vitriol, having been introduced through the manhole, the cover is put on, and the boiler set in motion. Steam and water may be admitted through pipes in the journals.

It is natural to suppose that the acid of the solution would dissolve the iron of the boilers, and make their use impossible, but the inner surface soon becomes covered with a protecting crust, which separates the liquid from the iron. The rotary is usually set in motion for the better discharge of the pulp, and the portion of the outside surface near the manhole over which the latter must flow, will become rusted from contact with the chlorine or acid; the inside coating may also peel off, and it cannot be denied that such bleaching boilers are a source of impurities, although not of a sufficient amount to do serious damage.

The principal argument in favor of iron rotary bleachers is that the chlorine gas cannot escape into the air, but will all be absorbed. This one good quality is, however, more than offset by the following bad ones.

The progress of the operation cannot be seen and controlled, and the influence of light is lost.

The friction produced by the motion of the rotary—objectionable in all cases—is much more so in this one, as the straw is already reduced to fibres. Although the boiler may move very slowly, yet it turns, and, if allowed to revolve for any considerable length of time, the fibres are sometimes rolled into little balls, which give to the pulp the appearance of fish eggs. It is very difficult, if not impossible, to straighten the fibres in these balls again, and they obstruct the screens and cause spots in the paper. We have seen many a boiler-charge emptied in this form, because it had been imperfectly boiled, was consequently difficult to bleach, and had to remain an unusually long time in the bleaching rotary.

230. The Hydrostatic Process, patented 1866, is based on the theory that gray pulp, mixed in a revolving boiler with a solution of chloride of lime, may be bleached with a smaller amount of chemicals, and more effectually if it is subjected to a strong pressure; for instance, of 100 pounds per square inch. The patentees promise a saving of soda ash in the previous operation of boiling, and recommend the digesting of straw with less than 50 pounds of steam-pressure.

It appears natural that the bleach solution, on having been forced into the innermost recesses of the pulp by the hydrostatic pressure, should find a better opportunity to exercise its influence.

The half-stuff, which has been obtained from straw by digestion with a comparatively small amount of soda, is well washed first, and then mixed with a fresh solution of bleaching powders in an iron rotary. The manhole having been closed and the boiler started, the hydrostatic pressure is put on by forcing waste bleach-

liquor, which has been drained from a previous lot of bleached pulp, into it by means of a strong pump, until about 100 pounds are indicated on the steam-pressure gauge. After it has been kept at that pressure for some time, usually about half an hour, the boiler is emptied, and the pulp treated as usual.

In discussing this process we can only repeat what has been previously said about *bleaching in rotaries* and about *forced bleaching*, all of which applies here.

The hydrostatic process is in operation at the Niagara Falls Paper Company's and the Rochester Paper Company's mills, the proprietors of which own the patent, and also at several other mills.

231. **Ozone Bleaching.**—John Campbell has received several patents for a process of bleaching which he calls the *ozone bleaching process.* The pulp is mixed with a weak solution of bleaching powders in an ordinary engine, and one or two fan-blowers force a current of atmospheric air into it near the bottom. Either chlorine gas generated in a retort, or a bleach-solution composed of various chemicals, such as chlorine, bromine, oxalic acid, and porous alumina, is brought in contact with the air on its passage to the engine.

It is claimed that either ozone is thereby created, or that the liquor is vaporized by the current of air, and reaches the engine in a finely-divided state, and that pulp can thus be bleached much cheaper than in the ordinary manner.

Ozone is not produced simply by the contact of the air with gas or solutions of chemicals, be the former propelled by a fan or otherwise; strong chemical or electrical action is necessary to transform the oxygen of the air into ozone (see article 35). It may be that the blast of air or gas agitates the pulp mechanically, and thereby assists the bleaching, but we are not aware that the invention has been very successful, or that it has found extensive application.

C. *Treatment of Straw-Pulp in the Beaters and on the Paper-Machine.—Conclusions.*

232. **Beating.**—The bleached straw-pulp is, as has been before said, already divided into fibres, and does not require any further cutting or reduction.

The author has prepared straw-pulp during several years in an ordinary engine, provided with a smooth piece of cast iron as a bed-plate. The pulp was only mixed in this engine, and finished by passing through a Kingsland engine on its way to the machine.

A slight brushing, such as is given by a good engineer in an ordinary beater, or in Kingsland's or Jordan & Eustice's engine, is all that is necessay.

233. **Paper-Machines.**—The paper-machines on which straw-paper is made are constructed like those used for rag-paper, with but one exception:

If metal, and especially iron, rolls are used for the first or wet-press, the wet sheet of straw-paper adheres to the upper roll with great tenacity, remaining on its surface until stopped by the doctor, instead of following the wet-felt, and causing fre-

quent breaks. Straw which has been imperfectly boiled has this quality in a higher degree than good pulp, probably because the resinous and gummy matters have not been thoroughly eliminated. If this be the only cause, or if the natural smoothness of straw-paper produces a strong adhesion in contact with the smooth surface of the roll, we must be prepared to meet the trouble.

After rolls of almost every possible material had been tried, it was found that those of tough, close-grained wood answered best. Maple and gum woods are frequently used, but trees, from which a roll of sufficient diameter, perfectly sound, without crack or knot, can be cut, are rather scarce. The author succeeded best with two rolls of gum wood of 25 inches diameter, both of which had been obtained from one tree. If a hole, knot, or other unevenness is found on the roll, it must be cut out square, and a block of exactly the same wood driven into it, tightly and in such position that its grain runs in the same direction as that of the roll.

In some mills these rolls are covered with jackets of alpaca cloth, cut as wide as the roll, and a little longer than the circumference.

One end is laid on top of the roll, and allowed to turn with it, so that the whole jacket will be wound around it; the overlapping loose end is then fastened to the lower part with two or three stitches by means of a needle and thread.

The pores of this cloth soon fill up, the jackets must be frequently washed and exchanged, and we prefer therefore a naked wooden roll, if a good one can be procured. Some arrangement, by which the wood can be perpetually washed and cleaned, must be applied to such a roll. The author has used for this purpose a sound 3-inch plank, about 8 to 10 inches high, which was fastened and pressed against the roll like the guard-board of a couch-roll, and a channel, about 1 inch deep and 1 inch wide, was planed all along through the middle of the 3-inch side, which touched the roll. The ends of this channel were plugged, so that the open part extended only as far as the wet sheet. A hole was bored upwards into the wood at each end of this open channel, and met by a $\frac{1}{2}$ inch pipe entering from the side of the board facing the wire. The water was introduced through the pipe near the front side, wetting the roll while passing through the channel, and left through the pipe at the other end. It is important that the board should fit close on the roll, so that none of the water can escape sideways from the channel. If it should leak out in any point the paper would be wetter and consequently weaker there than anywhere else, and perhaps break on the passage to the end of the machine. Wood can hardly be fitted tight enough on wood; the board is therefore covered with felt like the coucher-guard; the felt being bent into the channel and tacked to it.

Instead of this arrangement, two guard or doctor-boards may be used, the first one to catch the broken paper, and the second one to hold and spread across the roll a solution of soap, which is constantly replenished from a reservoir.

After a wooden roll has been running for some time, it becomes slimy; the paper begins to stick again, and it will be found necessary to renew the surface by removing from it as thin a crust as possible.

This can be done by holding a scraper formed like a large plane-bit against the roll while it is running; or the human hands may be replaced by a cross-head, which carries the plane-bit. An iron frame is for this purpose fastened to the pressroll-stands at both sides, stretching across the machine on the side of the roll which faces the wire, and upon it travels the cross-head, moved along the roll by a screw and hand-wheel. To allow the roll to be full in the middle, the screw may be somewhat sprung out.

If no mechanical arrangement like the latter is attached to the machine the wooden roll will become uneven from being repeatedly scraped by hand, and the paper, remaining wet and weak in the hollow places, will break frequently on its subsequent journey. It is therefore desirable to have two rolls on hand, one of which may be turned off while the other is at work.

If the mill is not supplied with a lathe, a very simple substitute may be provided, wherewith the wooden rolls can be turned or rather planed.

A frame is constructed for this purpose, on which one of the rolls may be revolved in bearings by means of a pulley, keyed on one of the collars adjoining the journals, and driven from the line shafting. A jack-plane is placed under a right angle across the roll, supported by two upright boards, which are bolted to the posts at the ends of the long sides of the frame, and which can be raised and lowered as may be desired. These boards should be set so that the turning roll will be scraped by the plane, while the latter is shifted by hand from one end to the other. The upper edges of the boards on which the plane is moved determine the form of the roll, and must therefore be perfectly true, or rather a trifle high in the middle.

We have also seen hard rubber rolls used for straw-paper on the first press, but they are not generally adopted for this purpose.

The paper, after leaving the wet-felt, is substantial enough to pass the ordinary second press without difficulty.

Straw paper, although sometimes hard and stiff when dry, is weak and flimsy while on the machine; it requires more attention, and breaks more frequently than rag-paper, especially if the details just described are not attended to.

Straw and other vegetable substances, which have to be prepared by the aid of large quantities of chemicals, are more destructive upon wires and felts than rags, probably because the acids are not always as well washed out as they should be; but this loss is compensated for by the small amount of power required for their preparation as compared with rags.

234. Conclusions.—The straw-fibre has qualities in which cotton, rags, or imperfections are deficient, and it forms a harder or stiffer paper than either of them. Neither one alone can produce as good a quality as mixtures of straw and rags, straw and imperfections, or of all three of these materials. Although good paper can be and is made from straw alone, mixtures are preferable.

In summing up the results, which have so far been obtained in this branch of the manufacture of paper, we find that the quality of the straw-paper, made by some

of our mills, leaves very little to be desired, and we believe that our future efforts should be more especially directed towards the reduction of its cost.

If the straw has been properly digested, so that pure fibres are obtained, there will be no difficulty in bleaching it, and we prefer, to all patent bleaching processes known to us, the old way of bleaching in the engine, as practiced for rags, with such modifications as have been suggested on the previous pages.

Abundance of soda will secure good straw-paper, whichever system of boiling may be adopted, and if we are forced, for the sake of economy, to use the smallest possible quantities of it, which may dissolve all extraneous matters (not fibres), we risk at the same time imperfect digestion and consequent failure.

Compared with these difficulties, it seems so natural to use plenty of soda in one short operation of boiling, and to recover it by evaporation, that we are at a loss to understand why it is not more frequently practiced in this country. We have no doubt that it will pay almost anywhere to evaporate very concentrated solutions; but near to the coal-mines even weaker ones would probably give a profitable return.

We would advise the location of mills for the manufacture of paper from straw and similar vegetable substances only, where both the raw material and fuel are cheap, to construct the digesters in any way, which insures perfect boiling with little or no motion of the pulp, and, with as small a volume of solution as possible, to recover the alkalies by evaporation, and to use them again mixed with fresh soda. (For particulars as to this evaporating process, we refer to Section VI of this chapter.)

This opinion is based on the present average prices of soda and coal, but would have to be modified if soda should in the future be obtained at considerably lower rates or if coal should become dearer.

Straw has the advantage over many other substitutes; for instance, over wood and esparto; that new crops of it are not only furnished by the soil every year, but that the quantity raised must increase with the demand for grain for our ever growing population. It may therefore be safely predicted that it will retain its place among the raw materials for the manufacture of paper, while others may be abandoned as soon as their present supply is exhausted.

Although the author has been compelled to give a rather unfavorable opinion on several new inventions and processes, he considers the manufacture of straw-paper in its present state susceptible of many improvements, and hopes that the inventors and pioneers, who venture their time and money in the endeavor to discover them, will be encouraged and rewarded in a more substantial form than by the consciousness only of having rendered a service to mankind.

SECTION V.

Esparto Grass.

235. Its Sources and Growth.—Esparto or Spanish grass (*Stipa tenacissima* or *Machrochloa tenacissima*) is a spontaneous product of the sandy or gravelly soils of Eastern Spain and Northern Africa, where it has been for centuries worked into baskets, matting, and similar wares, like our willows. The lands most favorable to its growth are found near the sea-coast, at moderate altitudes, exposed to the sun, and dry.

It is, however, not harvested by mowing, as the name "Spanish grass" would imply, but pulled from cylindrical stems called *atochon*, of which it forms the leaves. These stems are cylindrical, without knots, but covered with short hair, which makes them rough to the downward touch, and growing in root-clusters of from 2 to 10 feet in circumference.

If raised from seed, the stems require from twelve to fifteen years' growth before they produce annual harvests of esparto, and in the earlier years of their existence they are so tender that they may serve as food for cattle; they become more solid with age, probably through gradual formation of cellulose, and sometimes live for sixty years.

The leaves, or esparto, grow to a length of from 6 inches to 3 feet, and are pulled from the stems by hand; but this should only be done in dry weather, between July and October, as the *una* or "nail"—the point where the leaves meet the stem—becomes so tenacious in wet weather, that the esparto will not separate from the *atocha*, and often results in tearing up the whole plant. This is not only a loss to the proprietors, but the roots, being of no value to the paper-maker, injure the quality of the whole lot if they are not removed.

The short and sometimes discolored esparto from the coast is, from its fineness and tenacity, the first favorite in delicate manufacture, but the long, handsome, gold-colored esparto from the interior is a strong competitor even for delicate uses, and commands a higher price for other purposes. The name given to this quality is *garbillo* (sieve); the sieves for cleaning grain being made from it.

The leaves are rather flat during their growth, but become dry and closed when they ripen, and acquire the even, rush-like appearance of the esparto furnished by the trade.

236. Treatment in the Mill.—Three grades or qualities of esparto are sold to the paper manufacturer, all of which must be cleaned and sorted by hand before they

are fit to be made into pulp. This is done on such tables as are used for sorting rags; roots and flowers are there cut off and the weeds taken out.

As may be judged from its similar chemical composition (see article 205), esparto grass is treated on exactly the same principles as straw; it is boiled with caustic soda, washed, and bleached with chlorine solution. All that has been said about these operations in the section on straw might be repeated here, but it will answer as well to state the points only in which the treatment must be changed to suit the special qualities of the esparto.

Esparto is much heavier than straw, and requires no *breaking down* or cutting, in order to fill a boiler to its utmost capacity. It is therefore used in the dry state and of full length, as it comes from the sorting-room.

The motion of rotary boilers is, for reasons stated, objectionable for straw, but still more so for esparto, as its fibres curl up easier, forming those little fish-egg-like balls, which are a source of trouble to many paper-makers.

It is therefore frequently boiled in so-called *vomiting tubs*, constructed on the same principle as those described and represented in Fig. 118.

Solutions of caustic soda are prepared for the digestion of esparto in precisely the same manner as for straw, but the proportion of soda ash used for the former may, according to the best information which we could obtain, be somewhat smaller —perhaps as much as one-third less. We say "perhaps," because, with esparto as well as with straw, this depends to some extent upon the purity and quality of the raw material and upon the way in which the operations are conducted.

Esparto contains nearly 10 per cent. more fibres or cellulose than straw, and must necessarily produce more paper. The statements as to its yield vary from 40 to 50 per cent., but we are rather inclined to put it nearer to the smaller figure.

In order to produce a good quality of paper, esparto, like straw, must be digested, so that its fibres will be freed from all foreign or incrusting matters; but the operation cannot be conducted with such accuracy that the 56 per cent. of cellulose which it contains will be fully obtained, and additional losses must be suffered by the subsequent operations of washing and bleaching, and finally on the paper-machine.

Esparto fibres, being tougher than those from straw and even from soft rags, are consequently more valuable, and enter largely into book and writing paper.

The recovery of soda ash by evaporation is more generally practiced in England than in the United States, and makes the manufacture of paper from esparto more economical.

237. **Supply.**—When esparto was, about the year 1860, first used on a large scale for the manufacture of paper, it could be drawn from the accumulated growth of centuries, and its supply seemed inexhaustible, but the increased demand, rising to 140,000 tons in 1871, and the consequently much higher prices paid for it, caused forced cropping, and in many cases extermination of the plant to such an extent that the yearly decrease of its production amounts at present to from 2 to 7 per cent., and in some localities even to 10 per cent.

It is doubtful whether esparto can be cultivated with profit anywhere, except where it grows spontaneously, but, even if this question should be decided favorably, and it should form in future times one of our staple crops, from twelve to fifteen years will elapse before any return will be obtained from the seeds.

The supply is meanwhile decreasing, and if the American paper-makers should enter the market to compete for it with the Europeans, they would thereby directly contribute to raise its price, and also indirectly the price of European rags. England manufactures the soda ash and bleaching powders, the cost of which forms the heaviest item in the production of paper from esparto and other vegetable fibres, and, being destitute of an abundant supply of vegetable fibres at home, cannot afford to give up esparto.

As long as the American paper trade will be dependent on England for its soda and bleaching powders, it should content itself with drawing from Europe rags only, and endeavor to find among the products of this vast continent the additional raw material for its paper. But why does it not arise to a full appreciation of the importance of an American supply of soda and of bleaching powders? It is full time that it had done so.

SECTION VI.

Wood.

238. The Works of the American Wood-Paper Company.—Paper was made from wood as early as from straw, but only on a small scale until the works of the American Wood-Paper Company had been erected.

Charles Watt and Hugh Burgess received a patent of invention in England, August 19th, 1853, and in the United States, July 18th, 1854, in which they claim:

> "The pulping and disintegrating of shavings of wood and other similar vegetable matter for making paper, by treating them with caustic alkali, chlorine, simple or its compounds with oxygen and alkali, in the order substantially as described."

The process described in the specifications has been much improved upon, but we mention the claim because it has played an important part in the lawsuits of the company.

Mr. Hugh Burgess, one of the patentees, is the manager of the American Wood-Paper Company's works, at Royer's Ford, Pa., where 5 tons of wood-paper and pulp are made every day.

The new works of the same company at Manayunk, Philadelphia, are of a capacity of 15 tons of white wood-pulp per day; they are situated between the Schuylkill River and canal, flanked by railroads on both sides, and driven by a water-power rented from the canal company. They were built in 1865, at a cost of over $500,000, and are leased to Messrs. Jessup & Moore and Martin Nixon, whose mills work up the pulp on nine paper-machines, after it has been previously mixed with rags in beaters.

239. Treatment of the Wood.—The wood, mostly poplar, is brought to the works as cord-wood of 5 feet lengths. The bark having been stripped off by hand, it is cut into slices of about ½ inch thickness by a cutter, or rather chopper—a machine looking like a feed-cutter on a large scale. Four steel knives, from 8 to 10 inches wide and from 12 to 15 inches long, are fastened in a slightly inclined position, to a solid cast-iron disk of about 5 to 7 feet diameter, which revolves with a high speed, chopping the wood, which is fed to them through a trough, into thin slices, across the grain. This trough must be large enough for the reception of the logs, usually from 10 to 12 inches wide, and it is set in such a position that the logs slide down towards the disk. This slanting position only assists the movement of the logs, while a piston, which is propelled by a rack, pushes them steadily forward, until they are

entirely cut up. The piston or pusher then returns to its original position, fresh wood is put into the trough, and the operation repeated.

It has been stated to us, that with one of these cutters, 40 cords of wood may be chopped up in a day. The works at Manayunk are supplied with two of them, situated so that the slices fall directly into boxes fastened on trucks, which are pushed to an elevator, as soon as they are filled, and hoisted up two stories to the floor from which the boilers are filled.

These boilers are upright cylinders, of about 5 feet diameter, and about 16 feet height, with semi-spherical ends, provided inside with straight perforated diaphragms, between which the chips from one cord of wood are confined. Solutions of caustic soda, testing 12 degrees on Baumé's hydrometer, are introduced with them, and fires are started in furnaces underneath. (The boilers at Royer's Ford are heated by steam, circulating through a jacket which covers its bottom and sides.) When, after six hours' boiling, the digestion is finished, their contents are emptied with violence, under the pressure of not less than 65 pounds of steam which had been kept up inside. A large slide-valve is for this purpose attached to the sides of each boiler, close to the perforated bottom diaphragm, and connected by a capacious pipe with a sheet-iron cylinder of about 12 feet diameter and about 10 feet height, which receives its contents —pulp, liquor, and steam. The object of these large chambers, one of which serves for two boilers, is to break the violence of the discharging mass. The steam is taken off through a pipe on top of each one, and conducted through a water-reservoir, while the liquid solution of pulp flows through a side opening and a short pipe at the bottom into movable boxes. These boxes are flat iron drainers, large enough to hold the contents of one boiler, and mounted on wheels; they can be pushed on iron rails right up to and under the collecting-chambers, in positions suitable for the reception of the pulp.

Ten digesting-boilers are located in one straight line in a building of 132 feet length and 75 feet width; the main line of rails runs parallel with the line of the boilers, side-tracks extend from it to each one of the chambers, and a turn-table is supplied at every junction. The drainer-wagons can thus be pushed from the side-tracks on to the main line, which leads to the washing-engines in an adjoining room.

The tracks are underlaid with iron pipes or sewers, arranged so that they will receive all the liquid which drains off from the wagons. The latter remain on the side-tracks, until the pulp is ready for the washing-engine, and, after the principal part of the liquor has passed off, some warm water from the receiver, which has been heated by the blown-off steam, is sprinkled over the pulp by means of a hose, with the object of extracting all the liquid which is concentrated enough to repay evaporation.

The contents of the wagons, obtained from as many boilers, are then furnished into two washing engines, each one of which has a capacity of 1000 pounds of pulp; but the water, which is poured forth by the cylinder-washers, being too diluted for evaporation, is allowed to escape. The pulp is emptied from these engines into two stuff-chests, and from there forwarded by pumps to two wet-machines of the kind represented by Figs. 92 and 93.

The screens of these wet-machines retain all impurities derived from knots, bark, and other sources, and the pulp or half-stuff obtained is perfectly clean and of a light-gray color. It is bleached in engines with a solution of bleaching powders—like rags—emptied into drainers, and kept there with the liquid for twenty-four to forty-eight hours, or long enough to make the use of vitriol unnecessary.

The portion of the white pulp, which is to be worked up in the adjoining mill of Mr. Martin Nixon, is taken from the drainers into boxes running on trucks and forwarded in a moist state; but all the pulp which is to be shipped to a distance must be made into rolls on a large cylinder paper-machine with many dryers. The object being only to dry the pulp, and not to make paper, a very heavy web can be obtained, as the water leaves this pulp freely.

240. Recovery of Soda by Evaporation.—The liquid, which has been drained from the pulp, and gathered underneath the track, is conducted in pipes to a separate building to be evaporated. The outline of this building is a circle of about 200 feet diameter, and the centre is occupied by a large smoke-stack, against which all the furnaces converge, while the fire-hearths are near the periphery. The furnaces are very long, and the gases of combustion or smoke are compelled to travel a considerable distance, and distribute their heat both above and below their route before they can escape through the chimney.

The liquid is pumped into large iron tanks adjoining the stack, around which the gases of combustion circulate before escaping finally. From there it gradually descends through a series of flat iron pans until it reaches the reverberating calcining furnace, situated next to the fire-hearth, and exposed to the heat from the fire and gases which pass over it. The tough mass is there stirred up with rakes from side-doors, and drawn out as soon as it is perfectly calcined or burnt to cinders, so that all vegetable matters, or anything not of a mineral nature, will be driven out, and nothing but a *black ash* remains.

The soda in this *black ash* reappears as carbonate, with the exception of a very small portion which may have combined with silicates and become insoluble. The ulmic acid which gives to the extract solution of wood its dark color, is the same which is formed by nature from decaying vegetation, and can frequently be recognized in swampy lands. It is entirely destroyed by the calcining process.

The evaporating furnaces may be different from those described, but the principle is always the same. The best constructed evaporators are those in which the largest quantity of liquid can be reduced to ash with a given quantity of coal and with the least labor.

If the liquor is too much diluted, the expenses of recovery, which include besides coal and labor, frequent costly repairs and renewals of the evaporating pans, may be higher than the value of the soda ash. Any soda liquor testing 5 degrees or more on Baumé's hydrometer is, at the ordinary market prices of coal and soda ash at Manayunk, considered strong enough for evaporation.

As much as 75 to 80 per cent. of the soda ash can thus be recovered in the form

of *black ash*, which must be mixed with fresh soda, causticized with lime, and used for another solution in the usual way. The sediment obtained from this second solution is at Manayunk redissolved with water, and conducted into large brick cisterns, filled with cinders, ashes, and broken bricks, through which the clear liquid filters, and is used in the place of water for another solution of caustic soda, while the insoluble impurities are retained on the surface. These filters answer a double purpose, as they not only extract all the soda which may have been left in the sediment, but also collect the lime, silicates, and impurities in such a manner that they can be carried away, instead of being allowed to escape into the river and to pollute its waters.

The free escape of soda liquor, loaded with extracts of straw, wood or esparto, into rivers or creeks has, in some places, become such a serious nuisance that manufacturers are compelled by law to dispose of it in some other manner, and they have mostly adopted evaporation as the best means to this end.

The wood-pulp made at Royer's Ford and Manayunk is perfectly clean, of a soft, white, spongy fibre, and the larger portion of it is mixed with a small proportion of rags and worked into book and fine print-paper. At Royer's Ford the company manufacture fine colored envelope and book-paper from this wood-pulp alone, or mixed with white paper-shavings. The fibres are deficient in strength, but unsurpassed as a material for blotting-paper, and they are very much liked by the printers.

Poplar, or more correctly *liriodendron*, furnishes very white fibres; it is easily digested, and generally preferred to other woods for the manufacture of pulp; its fibres, however, are short, and it is, therefore, sometimes found expedient to mix them with the longer ones, from spruce or pine, although the latter, which contain much resin, resist with greater obstinacy the influence of the dissolving agents' which are brought to bear upon them.

241. Yield of Fibres, Bleaching, and Conclusions.—Dr. Charles M. Cresson, in his testimony as an expert, has given the quantities and lengths of fibre, contained in different kinds of wood, as ascertained by him from a large number of experiments, as follows:

	Percentage of Pulp.	Length of Fibre.
Maple-wood, unseasoned,	21.2	0.0300
Cherry-wood, seasoned,	32.	0.1000
Yellow pine, "	36.5	0.3750
Hemlock, "	45.	0.2675
Ebony, "	14.5	0.0500
Ash, unseasoned,	20.6	0.0625
Poplar, "	30.	0.0162
Poplar, seasoned,	37.	
Spruce pine, "	32.	
Dog-wood, "	35.7	

	Percentage of Pulp.
White pine, seasoned,	33.25
Walnut, very dry,	42.
Hickory, seasoned,	22.6
Oak, unseasoned,	20.6
Chestnut, "	25.17
Birch, seasoned,	40.
Box-wood, "	33.64
Lignumvitæ, seasoned,	15.8
Mahogany, "	29.
Rose-wood, "	30.25

These proportions can, however, hardly be extracted on a large scale, even by the most careful digestion, and a portion of the pulp must be lost in the subsequent operations.

Dr. Cresson states in the same testimony the results which he obtained from the treatment of wood-pulp with chlorine in solution, as follows:

"Chlorine acts with much energy upon portions of the intercellular matter, especially that adhering to the surface of the fibre, but I have failed to produce a satisfactory pulp by its use alone. Its use as a bleaching agent upon pure cellulose obtained by the full action of an alkaline bath under proper pressure I suppose to be purely molecular.

"From an impure pulp it would undoubtedly remove the incrust adhering to the fibre and dotted vessels, but this is done more cheaply and effectually by the proper alkaline treatment.

"The process of bleaching does not seem to indicate the removal of any such matters.

"I have carefully weighed samples of pure pulp before and after bleaching by chlorine and can find no appreciable loss. Again, the effect of the action of chlorine is not always to produce a white color; in most cases the color produced is white, but in others it has a grayish, and again a yellowish cast."

The Royer's Ford and Manayunk works get from 27 to 28 per cent. of pulp from young poplar wood, and about 30 per cent. from old air-dry poplar wood, one cord of which weighs from 2800 to 3400 pounds.

Wood contains a smaller proportion of fibres, and requires a larger quantity of soda ash (100 to 112 pounds for 100 pounds of paper) for its digestion than straw; the production of wood-pulp is, therefore, everything else being the same, more expensive. Its manufacture can only be made to pay by the superiority of the article produced, by the recovery of the soda through evaporation, and in a location favorable for the supply of wood, coal, and all other materials.

242. Other Systems of Boiling.—Another system of utilizing the waste liquor is to boil a second lot of stock with it, as is done in some mills with the Dixon boilers. It is, however, doubtful, whether the second lot of pulp (from straw) will not suffer in quality.

A new system of boiling wood is in operation at a mill in Maine. A strong solution of caustic soda is forced under high pressure, but cold, into a boiler loaded with chips of wood, with which it is, however, allowed to be in contact only during a very short time. The solution is soon drawn off again, and the wood emptied into a second boiler, where it is subjected to the influence of a high temperature, produced by steam circulating in an outside jacket. It is thus merely impregnated with caustic soda, and consumes only a small portion of the usual quantity. A good-looking brown paper is made at this place, but we have not heard of any white paper, except samples, being manufactured there.

243. Orioli Fredet and Matussiere's Patent.—Messrs. Orioli Fredet and Matussière, in France, received a patent of invention on April 25th, 1865, for the treatment of wood with aqua regia. The invention is based on the discovery that aqua regia, a mixture of 5 to 40 per cent. of nitric acid and 95 to 60 per cent. of hydrochloric acid, destroys all ligneous or intercellular matter, without attacking the fibre or cellulose.

After the wood or straw has been soaked in this acid, the surplus is drawn off, and the remaining solid part ground under vertically revolving millstones. The brownish-colored pulp thus obtained is then washed and bleached as usual.

Nitric acid, or its mixture with hydrochloric acid, is theoretically very well

adapted for the extraction of cellulose from wood, straw, and other vegetable fibres, but the difficulties which are encountered in the use of large quantities of them, are nearly insurmountable, and have prevented their practical utilization in the manufacture of paper. Very few materials are able to resist the corrosive influence of these acids; the vessels for the digestion of wood or straw would have to be covered with varnish or paraffin and well cemented glass-plates, all the pipes used for the escape of the gases and liquids would have to be of glass, and any escape of vapors or gases would have to be strictly avoided, as no human being could live in an atmosphere pervaded by them. Nitric acid also forms with cellulose the very inflammable *xyloidin*, a substance akin to gun-cotton, and the danger from this source would seem alone sufficient to forbid its use.

244. Sulphide of Sodium.—A patent has been obtained by Professor Eaton, of Brooklyn, N. Y., for a process of making *sulphide of sodium*, and for the use of that article as a substitute for carbonate or caustic soda in paper-making. Works for its manufacture are being erected, and nearly finished, by the Eaton Fibre Company at Brooklyn, New York.

The late Mr. John Priestley stated to the author, that according to experiments on a large scale, which he had caused to be made, the sulphide of sodium, besides being much cheaper, proved to be more efficient than caustic soda.

245. Adamson's Patent.—William Adamson, of Philadelphia, has obtained patents of invention dated July 18th, 1871, for the use of hydrocarbons in the production of paper-stock from wood or other ligneous substances. He recommends treatment with benzine in closed vessels, with 5 to 10 pounds of pressure, according to the quality of the wood. His digester consists of an upright cylinder, wherein the wood shavings or other materials are contained between two horizontal perforated diaphragms. The mass is heated beneath the lower diaphragm by a coil, through which steam circulates. The vapors which escape through a pipe on top of the digester are condensed by passing through a coil immersed in a cistern with cold water, and return to the lower part of the digester. The portion of the benzine, which has remained liquid, is saturated with the extract matters, and can be drawn off through a faucet at the bottom.

Benzine is a very cheap article, and the invention, even if not successful for wood, may be used with advantage for other purposes. It is, for instance, recommended in a separate patent, issued September 19th, 1871, for the extraction of pitch and tar from rags, and it may, perhaps, answer very well for the extraction of oil from rags and cotton waste.

Straw and other vegetable substances, as well as wood—the latter even in the form of shavings and sawdust—are rapidly disintegrated by this process.

The resultant products from experiments on straw were fine long fibres, and very fine white vegetable wax. The process has, thus far, not been extensively carried out, as the patentee has found it necessary to obtain, by further experiments, correct data and results before entering upon operations on a very large scale, which he intends soon to start.

SECTION VII.

Mechanically Prepared Wood-Pulp.

246. History.—Dr. Schaeffer, at Regensburg, Bavaria, had, over one hundred years ago, proposed the use of sawdust and shavings, by stamping them into a pulp, but the imperfect state of the machinery within his reach made success at that time impossible.

F. G. Keller, in Saxony, originated the idea of grinding wood by pressing blocks of it against a cylinder of sandstone revolving in a vertical position; but Henry Voelter, of Heidenheim, Würtemberg, Germany, took it up, and succeeded, after twenty years of labor and expensive experimenting, in bringing the process to its present perfection. To him belongs, therefore, the credit of having given us a new material, which, if it does not improve the quality of all papers, is, through its cheapness, profitable to the manufacturer, and by taking to some extent the place of rags, has assisted in keeping their prices within reasonable bounds.

247. Voelter's System of Manufacturing Wood-Pulp.—The wood is cut up into short blocks, four or five of which are pressed against one of the upper quadrants of the revolving surface of a cylinder of sandstone, which turns on a horizontal shaft, while the balance of the stone is surrounded by an iron casing.

The blocks are constantly pushed forward by screws operated by gearing, in the same proportion as they wear off.

Mr. Voelter says that levers and weights, in the place of screws, would not produce a uniform pulp; that he has tried to revolve the wood with or against the stone; and also to use the stone in a horizontal position, turning on a vertical shaft, but without success.

The wood must be pressed against the stone, so that the grain will run parallel with the axis, and that the fibres will be *torn off* by the rough surface, instead of being ground or powdered.

A small stream of water falls constantly upon the stone, and carries the pulp first through a rake, which retains the coarsest pieces of wood, and then to a wire-covered cylinder turning on its horizontal axis.

The pulp, which passes through the wire from the outside to the interior of the cylinder, is ready to be sorted, and for this purpose conducted through several revolving wires of successive coarser grades. The finest fibres only, are able to get through the meshes of the first fine wire, and are gathered in the receiver below, while the coarser ones move on, until they find openings suited to their grade.

The wood which is too coarse to pass through the wire-cloth on the first cylinder, is conducted to a *refiner*, where it is subjected to another disintegration, and then returned to the first cylinder by means of a pump.

A system of pulping and sorting, like the one just described, was put in operation by Mr. Voelter at the Paris Exhibition, 1867, where the assorted pulp, thus obtained, was pressed out between three pairs of press-rolls, through which it was carried upon an apron.

248. Operations of the Turner's Falls Pulp Company's Mill.—A considerable number of mills have been built in this country within the last few years, according to Voelter's directions, and working under his patents; and a description of the largest establishment of this kind, visited by the author, will probably bring the process more clearly to the reader's mind than mere theoretical explanations.

The mill is owned by the Turner's Falls Pulp Company, of Turner's Falls, Massachusetts, and is driven by turbine wheels, which are supplied with sufficient amounts of water for the production of 1000 horse-power, by the Water-Power Company at the same place, from their dam across the Connecticut River.

The building is of brick, 50 feet by 200, one story high, and contains twenty-four grinding stones, which are divided in equal numbers along the two side walls.

Poplar wood is used exclusively; it is furnished to the mill in short round logs, which are cut by a circular saw into blocks of 13½ inches in length (the width of the stones), and split lengthways by another circular saw, according to its size, into either two or four pieces. The knots in the wood, which have then become visible, are cut out by hand with an axe.

The waste derived from these preparatory operations is burnt under steam-boilers, and heats the building, or is sold as fuel to adjoining mills.

The blocks are furnished to the stones as they may be required, and reduced to pulp in the manner previously described.

The pulp from the twelve stones on one side is directly conducted into a coarse screen moved by knockers, and constructed like those used on paper-machines. It stands in the middle, between the two rows of stones, and the screened pulp flows from it through a trough to the sorting apparatus.

Two rows of sorters or *splinter-moulds*, as they are called, occupy the larger part of the space between the two rows of stones, corresponding with them also in numbers. They are 3 feet long, 2 feet in diameter, and are covered with No. 18 wire-cloth.

The twelve grinders on one side work together, and make only one grade, or No. 1 pulp.

They are set on a high framework, and a refiner is located under each one of them. These refiners consist of a lower stationary stone and an upper revolving one, like those of a flour-mill. They are, however, of sandstone, and cut in such a manner that they will tear and not pulverize the wood.

The coarse fibres or splinters, which could not pass through the wire, flow to these refiners, are reduced between the stones, pumped back again to the *splinter-moulds*, and return to the refiners until they are fine enough to get through.

The stuff-chest, which collects the pulp from the interior of all the wire-cylinders, supplies, by means of a stuff-pump, a board machine consisting of a making-cylinder and a first press. Six to eight thicknesses of the web of pulp are allowed to collect on the upper iron press-roll, when they are cut through with a wooden knife, and taken off in the form of boards.

The splinter-moulds of the other twelve stones are covered with No. 8 wire-cloth, and the fibres which cannot at once pass through it are simply removed and considered waste.

The larger part of the pulp, however, is fine enough for this number, and the waste does not exceed 5 per cent.

The No. 2 pulp, thus obtained without the use of refiners, is also formed into wet boards, but being much coarser, it sells at a lower price than No. 1.

The working surface of the stones is made rough by a steel roll covered with projecting points, which is pressed against it while running.

The frame carrying the steel roll is, for this purpose, fastened to the casing, whenever a stone becomes dull.

Besides this roughing there are channels, over $\frac{1}{4}$ inch deep, cut into the surface of the stone $2\frac{1}{2}$ to 3 inches apart. There are two sets of these channels, each forming an angle of 30 degrees with one edge; they cross each other in the middle, and carry the pulp off to both sides.

The pulp in wet boards contains about 60 per cent. of water, and is thus shipped to the mills. To find the exact proportion of wood contained in the pulp, one of the boards is weighed, dried in an oven, and weighed again. It is then drier than the paper-machine would make it, and as it is only sold air-dry, from 7 to 10 per cent. are added to the oven-dry weight.

When the atmosphere is loaded with moisture, it will not extract as much water from the pulp as when it is perfectly dry. Seven per cent. only is therefore added to the oven-dry weight on wet or damp days, but 10 per cent. on clear ones.

If a pulp shows, for example, on a damp day an oven-dry weight of 33 per cent., 7 per cent. or $2\frac{1}{3}$ pounds must be added to 33, making altogether $35\frac{1}{3}$ pounds of air-dry pulp for every 100 pounds of pulp shipped.

The Turner's Falls Company can turn out 5 tons of air-dry pulp per day by employing from fifty to sixty hands, and produces about 1200 pounds of air-dry pulp from one cord of poplar wood.

249. Treatment of the Pulp and Conclusions.—If the pulp is in store or transportation for a long time, it loses a large portion of its water by evaporation, becomes hard, and can only with difficulty be dissolved in the engines.

Voelter recommends therefore the building of pulp mills only, where suitable woods can be had at low prices, with ample water-power, cheap labor, clear water, and where the produce will be consumed in the neighborhood.

He prefers pine and fir wood for the felting power (length) of their fibres, and aspen and lime trees for their color.

The pulp from poplar wood will improve the color of darker grades, but injure the color of very white papers.

The fibres produced in this way cannot be pure cellulose, but are surrounded with the incrusting substances or intercellulose of the wood. Though they may have some felting power, they cannot be considered as a substitute for hemp or linen, or even for chemically-prepared fibres of wood and straw, but only as a convenient material which adds to the bulk and weight of the paper without requiring any preparation.

It is simply added to the pulp in the beaters, but, as it is necessary to dissolve it into the thinnest possible fibres, it should be subjected to the action of the roll for at least one hour.

If it is not well mixed with the rag pulp, the wood will come to the surface while on the wire-cloth, and make one side of the paper rough.

A larger proportion of wood can be used with strong pulp and heavy paper than with weak pulp and light paper.

250. Improvement Patents.—Since Voelter's machinery has been successfully introduced, a number of patents have been taken out for improved grinders.

Some inventors put them horizontally, or make the grinders of other material than sandstone; others coat only the surface of a cylinder with a composition of hard material.

We have seen at Curtisville, Berkshire County, Massachusetts, a narrow iron cylinder revolving vertically like Voelter's stones, the sides of which are filled with an artificial coat, made of a paste, which contains a large quantity of flour of emery, becomes hard in a short time, and resists the influence of water.

Two blocks of wood are pressed against each of the two flat perpendicular sides near the circumference.

Mr. F. Burghardt, the inventor, claims that he saves half the power used by Voelter's stones, and produces a better and more uniform pulp.

SECTION VIII.

Cane, Jute, and Manilla.

251. Growth and Gathering of Cane.—In the Dismal Swamp and along the rivers of North and South Carolina, as well as in the lowlands of the Mississippi, the country is covered for many miles with the spontaneous growth of a reed or cane, the botanical name of which is *Arundinaria macrosperba.*

This cane is a hollow tube, about 12 feet high, nearly white, and apparently composed of tough, strong fibres. The territory covered with it, is so vast and unfit for any other useful growth, that the supply of cane seems to be nearly inexhaustible, especially if it is considered that a new crop can be cut every three years.

The American Fibre Company have undertaken to utilize this material for the purposes of paper-making, and secured the methods by which it is done, with numerous patents.

The Norfolk Fibre Company, near Norfolk, Va., and the Cape Fear Fibre Company, near Wilmington, N. C., are working under these patents.

The Norfolk works, which we have visited, are situated on the Dismal Swamp Canal, near the track of the Norfolk and Weldon Railroad, about 4 miles in a straight line from Portsmouth, Virginia.

The cane is cut in the swamps along the canal with scythes, such as are used for cutting corn-stalks. Wherever large quantities are found in one body, a railroad is constructed of sleepers and 4 by 4 inch wooden rails. The cane, the heads of which have been cut off, is tied in bundles, taken on trucks to the canal, loaded on flat-boats which are capable of carrying 150 cords, and conveyed to the works.

The cost of labor (colored men) and transportation is reduced by this system so low that one ton of cane can be delivered at the mills for $3.

The bundles are opened where they have been landed, cleared of all refuse matter, and made into compact packages of 1 foot in diameter, which are forwarded on another wooden railroad to the gun-room.

252. Operations of the Cane-Fibre Mills.—The cane is disintegrated by the Lyman process, patented August 3d, 1858, in the following manner:

Strong cast-iron cylinders, 22 feet long and of 12 inches inside diameter, are laid horizontally on heavy frames, and provided with strong heads at both open ends. To fill them, the rear covers are taken off, as much of the cane as possible is packed in, and both ends are closed tight again.

The cylinders, being filled up, would not leave room enough for a sufficient quantity of steam; each one is therefore provided with a steam-dome, which consists

of a shorter cylinder of the same diameter as the gun, the T-shaped outlets of both dome and gun being bolted together near and above the rear end.

Steam is admitted into the loaded guns until the pressure-gauge shows 150 to 180 pounds, and kept so for about twelve minutes, when, by means of a long rod or trigger, the fastenings of the cover at the discharge end or *muzzle* are loosened, and it is allowed to drop out suddenly.

The steam in the dome then rushes out with such force that it carries the cane before it. On reaching the atmosphere, the steam, with which all the pores of the cane are filled, expands violently, thoroughly disintegrating it; and the load strikes a target, about 30 feet from the guns, as a mass of brown sugary-smelling fibre.

The discharge causes a report equal to that of a large cannon, and can be heard at a distance of several miles. The concussion of the air all around is so violent that it is impossible to stand unsupported anywhere in the gun-room.

It is supposed that the steam at its high temperature dissolves first the resinous and gummy matters, and that the cane is then torn asunder by the violence of the explosion. Whatever may be the correct theory, the disintegrating power of the operation is wonderful, and acts, as we are told, as well on wood and other fibrous substances as on cane.

A gun loaded with 100 pounds of cane can be discharged every fifteen minutes, and six are required to keep the hands constantly employed filling them. The four guns at the Norfolk Fibre Company's works, one of which is of a larger size, can turn out from 16 to 24 tons in twenty-four hours.

The full weight of the dry cane, less some dust and impurities, is obtained in perfectly dry fibres, which have very much the appearance of oakum, are packed in bales weighing about 320 pounds, and shipped either by rail or water.

The fibres in this form make a strong, spongy paper, which can easily be saturated with other liquids. They are therefore largely used for roofing-paper, boards, wrapping, &c. They have also been bleached by the same process as straw, and produced strong white paper; but the large quantity of tannic acid or tannin contained in the cane, makes the extraction of the clean white fibre more difficult and costly than from some other materials.

In order to extract all the parts which are soluble in water and to reduce the bulk of the fibres, the Cape Fear Fibre Company puts them through a washing process, which is described in an article in No. 5 of the *Paper Trade Journal*, as follows:

"The fibre is next submitted to the washing process. It is gathered up, thrown into large tubs, and passed by means of a continuous stream of spring-water thrown by a steam-pump under the rolls of four beating-engines, similar to those used in the paper-mills, except that the fibre passes from one to the other, instead of travelling round and round. It then passes on to an endless wire-apron, and is carried through several sets of iron rollers, the last set being covered with India-rubber. The fibre is thus squeezed of all water that will run from it, and comes off in a thick, solid sheet. By this washing the bulk is reduced one-third, being deprived of all the gum, dirt, &c.; next the fibre has to be dried.

It is slightly picked apart and thrown on to an apron, which leads it through feed-rolls to a picker, revolving at a high rate of speed, which thoroughly pulls it apart and throws it on the apron of the drying-house. This house is 70 feet long, and is heated by four steam-pipes running side by side.

"The endless apron travels slowly over these pipes, taking about twenty minutes to make the trip, and the fibre is taken off at the end perfectly dry. It is then baled by one of Dederick's hay presses, and made into bales averaging 500 pounds in weight. The pulp made from this is soft and admirably adapted for making paper, either alone or mixed with the harsher paper-making substances, such as straw, &c."

The almost inexhaustible supply of this material and the good qualities of its fibres make it very desirable that it should be utilized on a much larger scale than is done at the present time.

253. Jute and Manilla.—Before closing the chapter on substitutes for rags, it is necessary to enumerate Jute and Manilla, but we refer for the discussion of these fibres to the following Chapter V, Section IV, on Manilla Paper.

Chapter V.

DESCRIPTION OF THE PROCESSES OF MANUFACTURE OF SOME CLASSES OF PAPER AND BOARDS.

SECTION I.

Bank-Note Paper.

254. Necessary Qualities.—Paper which represents money and circulates as such, is frequently subjected to very rough usage, and must be strong and tough. The amount which it represents, and other matters relating to it, are printed on its surface; water-marks are often desired in the body of the paper, and it is therefore necessary that it should be manufactured uniformly and perfectly clean and clear. It is hardly possible to produce sheets on the paper-machine so that the water-marks will appear upon all of them in exactly the same proportions as in the original design, because the paper, being held in a state of tension only in the direction in which it travels, but not crosswise, will be unequally contracted. Hand-made paper is for this reason, and also on account of its superior strength, frequently used for bank-notes.

Counterfeiters have, however, with the aid of photography, found ways and means to imitate the water-marks as well as the most elaborate engravings so artistically, as to deceive not only the public, but sometimes even experts.

It has therefore become a matter of the greatest importance to devise a method which shall defy imitation.

255. The Paper Money of the Government of the United States.—The government of the United States has, from numerous propositions, selected the process patented by Mr. Willcox, and all the paper for the money issued by this government is at present manufactured on a 62-inch Fourdrinier paper-machine at the Glen Mills near West Chester, Pennsylvania, owned by Messrs. J. M. Willcox & Sons.

Short pieces of red silk are mixed with the pulp in the engine, and the finished stuff is conducted to the wire, without passing through any screens which might retain the silk threads. By an arrangement above the wire-cloth, a shower of short pieces of fine blue silk thread is dropped in streaks on the paper, while it is being formed.

Thus every legal tender note shows the red silk distributed all through the mass, and a streak of blue threads only in a certain fixed place.

The upper side, on which the blue silk is dropped, is the one used for the face of the notes, and from the manner in which the threads are applied, must show them more distinctly than the lower or reverse side, although they are imbedded deeply enough to remain fixed.

The mill is guarded by officials day and night, to prevent the abstraction of any paper.

Even the most inexperienced eye can perceive at a glance the presence or absence of these threads, and it is believed that paper of this kind cannot be made without expensive machinery. Unless the counterfeiters succeed in manufacturing or stealing it, they must give up their nefarious profession so far as these notes are concerned.

256. Manufacture of Bank-Note and Bond Paper.—Considerable quantities of bank-note and bond papers are manufactured in this country for individuals, corporations, and foreign governments.

At the paper-mill of Marshall Crane, at Dalton, Mass., these grades have been made a specialty for many years, and will, although they are, without exception, furnished by a Fourdrinier machine, compare favorably with the best hand-made ones.

Only the best of white linen, and especially cuttings of white, pure, flaxen threads, imported from Scotland and Ireland, are used. They are boiled in wooden tubs, washed and bleached in the engine with very little chlorine and without vitriol. The stuff remains in the beaters, which are supplied with brass plates, sometimes as long as from forty-eight to seventy-two hours. It is sized slightly with resin soap, and then runs over the machine, where it receives water-marks from the dandy-roll. The dried paper is passed through animal size, cut into sheets, and taken up to the loft like letter-paper.

These papers neither require a very smooth surface, nor will the water-marks admit of super-calendering; the sheets are therefore laid between fine pasteboards, alternating with them, and the piles thus formed are subjected for a considerable time to a strong pressure, whereby they obtain what is called a *dead finish.*

Messrs. Hudson & Cheeney, at North Manchester, Conn., make bank-note paper substantially in the same manner, but they dry it, after it has been sized in the web, by leading it to and fro over carrying-rolls in a warm atmosphere, and over heated dryers afterwards.

SECTION II.

Tissue-Paper.

257. Operations of a Tissue-Paper Mill.—From the thinness of tissue-paper it is difficult to handle; it must therefore be given as much tenacity as possible by being composed of very strong fibres, and it can be taken over a machine only, which has been constructed so that the paper will pass through with but little assistance.

A mill, which makes a specialty of fine colored tissue-papers, works in the following manner:

Hemp-bagging and a small proportion of cotton canvas are the rags used; they are each separately sorted, dusted out, washed in engines, bleached with chlorine solution, and emptied into drainers. The bleached pulp is mixed in beaters furnished with zigzag plates, washed, reduced, colored, and emptied into stuff-chests.

The paper is made on a cylinder machine with four copper 30-inch dryers, and at a speed of over 100 feet per minute. Copper dryers are used because the paper would stick to iron ones.

As it is indifferent on which side the tissue-paper is in contact with the presses, if we only succeed in passing it through them, and as it would also be difficult, if not impossible, to take it in the ordinary manner by hand from the wet-felt to the press-felt—these felts are disposed so, that the web passes in a straight line from the first to the second press, instead of entering the latter from the forward side.

The second press adjoins the dryers closely, leaving no space between them, and on its passage from the press to the dryers the web is supported by a wooden roll. The dry paper passes through one set of three calender rolls, is then trimmed by slitters, and wound on an old-fashioned adjustable reel. The diameter of this reel must be made larger and smaller for sheets of different lengths, and it is built as light as possible; the paper not being stiff enough for a cutting-machine, is taken from this reel by hand and cut on a table.

When the stuff has been admitted to the machine, and the web appears on the wet-felt, a dry sheet of paper is passed through the press with it. This sheet is thereby closely joined to the wet web, and serves to lead it through the other parts, as it would hardly be possible to take hold of the new wet tissue-paper without tearing it.

A 40-inch cylinder machine of this kind may, if running fast, produce nearly 1000 pounds of tissue-paper in twenty-four hours.

SECTION III.

Collar-Paper.

258. **Its Manufacture.**—Paper collars are used in such large quantities that several paper-mills have found it to their advantage to manufacture collar-paper as a specialty.

It must be thick and spongy, and at the same time strong and flexible enough to be bent and folded without breaking; it is therefore composed of some linen and of a large proportion of cotton rags, both of which should be given as much time as possible in the beaters, in order to obtain the full length of the fibres.

Although it can be and is made on Fourdrinier wires, it is acknowledged that cylinders are preferable, and one of the best mills for paper of this kind uses a machine with three forming-cylinders.

The difficulty of pressing the water out of such triple sheets is overcome by surrounding the upper roll of the first press with a short, endless wire-cloth; the paper thus passes between it and the felt, which covers the lower roll, and loses water on the upper side as well as on the lower one. It is, however, not to be understood that the wire-cloth forms a jacket for the press-roll, it being considerably wider and supported by two carrying-rolls above the press in such a way that it is only in contact with the press-roll where it rests on the paper.

The cotton cloth with which paper collars are frequently lined is mostly pasted on the paper by the collar manufacturer, but in a paper-mill at Holyoke it is attached to it on the paper-machine.

The cotton cloth in rolls is suspended above the machine, joins the paper before it enters the presses, and passes with it through the rest of the machine.

SECTION IV.

Manilla Paper.

259. Manilla Grass.—Manilla grass, a product of Eastern Asia, is extensively manufactured into ropes and bagging, and reaches in due time, like rags, the paper-mill. It is considered the strongest of all known fibres, and furnishes the well-known tan-colored paper.

Common tissue, wrapping paper, tags, and all kinds of bags, from the ordinary ones up to flour bags, are, or rather have been, made of it, until the consumption of these articles had increased so enormously, that the supply of Manilla stock became entirely insufficient, and new materials had to be substituted for it.

This has been done, and found so profitable that the larger part of all our Manilla papers may be said to consist rather of anything else than Manilla stock.

260. Jute.—Jute is another East India fibre similar to Manilla grass, which enters largely into woven goods of different kinds. Its butt ends, as well as all the fibres which are unsuitable for the loom, are abandoned to the paper-maker. They are virgin fibres, which have never been manufactured into anything or exposed to any wear and tear, and being considerably cheaper than Manilla stock, although not so strong and tough, make an excellent substitute for it.

We have seen mills which turn out from 5 to 6 tons of Manilla paper per day, where not a pound of Manilla stock could be found, while they were filled with jute-butts.

Wc add here an extract from an article on jute in No. 7 of the *Paper-Trade Journal.*

"Jute is a fibrous plant that grows to a thin stalk, varying from 6 to 12 feet in height. It is raised in the low lands of the East Indies. The jute plantations are operated somewhat on the system of rice plantations. The water used for flooding purposes is taken from the rudely-coustructed reservoirs filled by the meltiug snow on the Himalaya Mountains. The plant is kept growing in about 18 inches of water, which prevents the parchiug rays of a tropical sun from destroyiug it. When the stalk has attaiued its growth, it is pulled up by the roots or cut off near the root. It is then laid out in bales like wheat or rye, and prepared for market. The bark is first removed; the root is cut off where it is pulled up with the stalk, and where the root is not originally kept, the hard lower end of the stalk is cut off and thrown into a class commercially known as jute-butts. The remainder is then assorted with regard to length, strength, fineness, and lustre of the fibre. The first quality is a beautiful, clear, long fibre, much of it resembling in appearance blonde hair. This is especially used for chignons,

but is also used in Scotland in the manufacture of fine jute cloths. Canvas for linings, cloths for making cheap duster coats, and a variety of goods of that description are made in Dundee, Scotland, of a mixture of fine jute and linen or cotton. The goods into which finer grades of jute are manufactured in Scotland are too numerous to mention. Many kinds are sold as all linen, when actually composed of jute and linen. These mixed cloths are called 'union cloths.' It is a singular fact that we are not now making any of them in this country.

"The second and third qualities of jute are determined by inferiority of length, strength, fineness, and color of the fibre. Some planters and merchants in the East Indies have four qualities of jute. It will thus be understood wherein the fibres commercially known as jute and jute-butts differ. The one is the stalk itself, which is all fibre except the thin, scaly, and easily-removed bark; the other is the harder and coarser fibre near the root, which is discolored by the water and becomes dark after being subjected to the intense heat of the sun in the tropics.

"Jute rejections are simply a mixture of all kinds of jute scraps—frequently fine jute that gets tangled till unfit for sale as first, second, or third class, and frequently pieces of butts; in fact, they are exactly what the name implies—rejections of jute and jute-butts. Those who use jute in this country will not buy rejections. They are used the same as butts for the coarsest matting, for heavy bagging, and for paper-stock. They bring in the market about the same price as butts."

The February number, 1873, of the *Paper-Trade Reporter* contains the following interesting article on jute-butts, written by the editor, Mr. Champion Bissell:

"Paper manufacture has, within a very few years, received three distinct and noteworthy impulses from the successive discoveries of the use of straw, wood-pulp, and jute-butts. All these have become recognized factors of paper industry, and it is difficult to say how this industry would have prospered without them.

"It is a noteworthy fact, that as civilization progresses and the populations of civilized and enlightened nations become denser, rags and other waste materials do not in like proportion increase, or, at any rate, do not in like proportion find their way to the paper-mill. Therefore the price of these materials rises, and inventive talent immediately looks about for substitutes. Therefore England reached out to Spain and took esparto, Germany took the wood of trees, and the United States took straw, and afterwards the lower portion or 'butt' of the Indian jute-plant.

"How it happened that during so many years, while paper-makers were consuming old jute in the shape of gunny bagging, burlap bagging, and jute rope, no one ever thought of using the raw fibre itself, is one of those mysterious yet undeniable facts that baffle all investigation. During these many years, while England and the United States, and in a less degree the Continent, were importing jute for cloth and cordage and bagging purposes, it was made a condition at the Calcutta jute packing houses that planters and factors who sent jute to be classified and packed must at their own cost remove the butts. These butts, from 6 to 12 inches in length, being of precisely the same nature and fibre as the rest of the stalk, but of less pliancy, owing to a larger adherence of bark, were regarded as worthless, and while the world was clamoring for fibre, were thrown upon the dunghill.

"Meanwhile, gunny bagging, which from its first use as paper-stock up to 1861 had vibrated between $1\frac{1}{2}$ to $2\frac{1}{4}$ cents, rose to 8 cents, and in 1867 settled to 4 cents, where it remained firmly. And there, and probably higher, it would have been to-day had it not occurred to a Calcutta merchant that if jute fibre in that shape was so valuable as paper-stock, jute fibre in another shape might be valuable also. This conclusion seems to us perfectly natural, and we can never cease to wonder that it was not earlier arrived at.

"The statistics of butts, as laid before our readers monthly, are sufficiently familiar. The crop of jute, though large, is limited definitely to the wants of commerce, and the annual cutting of butts from

the foot of the jute-stalk is, with remarkable recurrence, about 200,000 bales of 400 pounds each. It is on their present and prospective use in this country that we intend more particularly to treat in this article.

"At present they are principally used by manufacturers of manilla paper and of cotton bagging. Dismissing the latter mode of use as foreign to the interest of the paper trade, we come to their special use as a fibre for manilla paper. In this mode of use, after being boiled in a rotary boiler, and beaten from four to eight hours, they produce a smooth, tolerably strong, tan-colored paper, or, by the addition of bleach, a cream-colored paper, which is good enough for a wrapping manilla and pattern-paper; although no one has yet succeeded in making it long-fibred enough for bag-paper, or for wrappers where maximum of strength is desired. In this latter case, the manilla-fibre stands unrivalled.

"Just so far, however, as butts can be used for manilla papers, even to largely mixing with manilla rope for making bag-paper, they are profitable, because no fibre reaches the mill so absolutely clean, and on which the manufacturer can base calculations with so much certainty. The bales contain neither dust, moisture, nor foreign material. They are absolutely jute fibre and nothing else; and large manufacturers who are making double sets of contracts at once in this market—that is, contracts to deliver paper on one side and contracts to receive butts on the other—calculate with accuracy the cost of the paper from the cost of the butts. There is no other class of stock—not even white shavings, not even the high grades of white rags—from which certain results so surely flow.

"We do not mean to say that every manufacturer produces the same quality of paper from a given quantity of butts. On the contrary, different modes of treatment and different grades of bleaching lead to results that differ by 20 pounds in 100. That is to say, some manufacturers produce 70 pounds of paper and others only 50 pounds out of 100 pounds of butts. But the manufacturer who produces 70 to-day will, with like processes, produce 70 to-morrow, and so on indefinitely; for the stock is uniform, and so the results of one day furnish a perfectly safe basis for calculation for the next.

"The bleaching process rapidly reduces the product of butts. Jute fibre contains in combination a large quantity of coloring matter. Jute-butts contain more of this than gunny bagging contains, although the bagging is jute fibre. This arises from the fact that gunny bagging is more or less exposed to the action of the sun's rays, which act upon its surface as a bleaching agent. Chlorine gas aided by water combines with this vegetable coloring matter, which in the jute fibre exists to a large extent, and destroys it as weight in the fibre, the chlorine and the atoms of coloring matter passing off together. Now, these atoms of coloring matter are a noticeable proportion of the fibre, and therefore the more highly we bleach the less weight we produce. Careful experiments, undertaken at our request by manufacturers, indicate that of a *highly bleached* paper we can produce 50 pounds from 100 pounds of butts. This product, however, with the aid of wood-pulp and clay, can be increased very materially.

"And this leads to the second part of our subject, namely, the prospective use of jute-butts. It is not likely that men will forever go on reading newspapers and books printed on perfectly white paper. The human race is in the habit of committing many popular and inexplicable follies; among these is the folly of reading by means of black letters imprinted upon a white surface. The contrast of black and white is not only disagreeable, but dangerous to the eye; and oculists are agreed that it is one cause of the early decay of the eyesight among reading nations. But whether we use black or blue for printers' ink, we ought to use buff, or yellow, or kindred colors for the groundwork. It is a well-known fact that nearly all press-writers, who from necessity write a great deal at night, use buff or manilla paper. And the reason why they use it to write on is a good reason why we should use it to read from, namely, that it is more wholesome for the eyesight.

"Artificial colors are expensive, and after we have once bleached a pulp white, it costs at least a cent a pound, and often more, to color paper. But if we use jute-butts to produce a paper on which to imprint types, we save two costly processes, namely, bleaching the pulp white, and then add-

ing an artificial color. Bleach the paper, of course, we must; but only to the extent necessary to produce an agreeable buff color; then we have a smooth, speckless sheet of paper, and all that is needed is that some great newspaper shall set the fashion of using it.

"At the threshold of fashion, science must pause. Medical science for a century has been powerless to abolish the corset, which physiologists say is a woman's worst enemy; and this impotency of science happens because corsets are the fashion. So white paper is the fashion, owing to the fact that our forefathers, not having bleaching powders, used as clean stock as possible for book-paper, and thus produced a whitish paper which *was* the fashion, and thus prepared the way for a perfectly white paper, which *is* the fashion. How long it will take to educate the popular taste to our real optical needs is a question. The five great New York daily morning newspapers could do it in a few months.

"But whether this result comes sooner or later, it is a great advance in our paper industry to have added 72,000,000 pounds of clean fibre to our yearly stock in process of manufacture. This fibre, we think, is destined to be always cheap, probably never rising above 3 cents a pound, and, as such, it will be an important contribution to the prosperity of the American paper-maker."

261. Process of Manufacturing.—Both manilla and jute are boiled in rotaries, but some experienced manufacturers prefer for jute-butts tubs constructed like those described for old paper and represented by Fig. 118. They claim that the revolving motion of the boilers injures the jute fibre, and that slow treatment with a moderate temperature is preferable to quick work with a high pressure of steam.

Whether they are boiled in rotaries or in tubs, both manilla and jute must be treated with a liberal quantity of milk of lime; from 15 to 25 pounds of lime per 100 of raw material should be sufficient, but some manufacturers use as much as 50 pounds of lime for 100 of jute. If manilla or jute is boiled with a solution of caustic soda, like straw, its fibres may be obtained pure; it can then be easily bleached and worked into white paper.

If an ordinary, rather dark-looking manilla-paper is to be made, the pulp is washed and beaten ready for the machine in one engine.

By bleaching the pulp in the washing-engine, and emptying it into drainers, the color can be much improved, and a light buff-colored paper is obtained.

The bed-plate on which the largest quantity of this pulp can be ground in a day, is usually given the preference; manilla paper-mills are, therefore, the best customers for zigzag and similar plates. Manilla grass will furnish strong paper, even if it be beaten quick and short, but the weaker jute should remain a much longer time in the engine, if it be desired to make a paper which resembles the former in strength as well as in appearance.

It is questionable whether Fourdrinier or cylinder machines should be used, and both kinds can be seen in manilla mills. Many experienced paper-makers contend that paper made on a double, or two-cylinder machine, is stronger than that of the same thickness made on a Fourdrinier machine.

It is true that the fibres on a Fourdrinier wire intertwine and felt themselves in all directions, while they are laid lengthways only on cylinders; but if a heavy paper is on the wire, and we imagine it horizontally split in two sheets of equal thickness,

the lower portion, resting on the wire, must be much better made than the upper one. The paper made on two cylinders consists of two equally well-made halves, and perhaps makes up thereby for the constitutional inferiority of the cylinder paper as compared with that made on a Fourdrinier machine.

A spot of grease or paint on a Fourdrinier wire will make a thin place or a hole in the paper at every turn, while the faults caused by the deficiencies of one cylinder are on double-cylinder machines covered by the paper from the other one.

It is difficult to form heavy manilla paper on the wire-cloth, because the pulp is always long and slow, and can only with difficulty be deprived of its water. Thick manilla papers, such as are used for flour bags, are therefore generally run over machines with two or three forming cylinders.

262. Bogus Manilla Paper.—The good qualities of real manilla paper have made it such a favorite with the public that the paper-makers have found it to their interest to give to common wrapping paper as much as possible the same color and appearance.

A cheap article of such bogus manilla is made of waste or old wrapping-paper and straw, colored with Venetian red in the engine; sometimes a small portion of bagging, or of other hard stock, is added, but the bulk of it consists of old paper and straw only.

SECTION V.

Tobacco Paper.

263. Its Manufacture.—The smoke of the paper, wherewith cigarettes are covered, mingles with that of the tobacco; it is therefore natural that attempts should have been made to manufacture it of tobacco instead of rags. An article of this kind has been successfully made in large quantities in the following manner:

Tobacco stems, otherwise a worthless material, were boiled in such tubs as are used for waste paper, without having been previously cut or dusted. The water used for boiling contained lime in solution (not as milk), and was perfectly clear, and as one thousand pounds of water can only dissolve about one pound of lime (see page 26) very little of the latter was required.

The boiled stems were beaten in an engine with about 5 to 10 per cent. of manilla half-stuff, to which the extract of the tobacco stems, obtained from the preceding boiling operation, had to be added instead of water. This juice gave to the paper the desired tobacco flavor, while the manilla fibres gave it strength enough to run over a paper machine in the ordinary manner. It burned, when dry, with a white ash, like a tobacco leaf, which it also resembled closely.

SECTION VI.

Paper from Cotton Waste.

264. Systems of Manufacturing.—A small proportion only of cotton is lost while it is made into thread, but the quantities consumed by the civilized world are so enormous, that the waste is sufficient to supply many paper-mills.

It is sorted according to its origin into several qualities, the lowest of which are the sweepings of the mills.

The principal difficulty in the manufacture of paper from cotton waste is, to get

rid of the numerous impurities, and especially of the cotton-seeds. Many paper-makers who have succeeded in making good paper from cotton waste, keep their methods secret, but enough is known to give a general outline of the operations.

The waste is, like rags, passed through cutters, and carried by aprons into thrashers or devils, which beat out its impurities by violent action, and permit them to escape through coarse wire-cloth or grates. It is impossible to make clean pulp if this part of the operations is not conducted in a thorough manner.

To eliminate from the cotton fibres all foreign substances, especially the grease and the shells of cotton-seed, the waste must be boiled like straw in a solution of caustic soda, although with a much weaker one. By this operation, which is mostly carried on in rotary boilers, every part of the waste, except the cotton fibres, or cellulose, is dissolved, but yet not thoroughly enough for the production of fine paper.

The paper-makers who, more than thirty years ago, first used cotton waste, packed the contents of each boiler, after they had been emptied, and stored them in a room provided for the purpose. The waste, being thus closely confined and moist, was given all the conditions necessary for putrid fermentation; and the decomposition, which the fatty and other extraneous matters thereby underwent, was assisted by the presence of soda; the whole mass became heated as the transformation progressed and gradually cooled down again, as the most susceptible material became exhausted. These changes were carefully watched, and when the mass showed by a decrease of the previously elevated temperature, that the process was finished, it was taken to the engines, washed and bleached like rags, and worked into good print and book-paper.

This method was quite successful, but as the process of fermentation required from ten to fifteen days, it has, like the process of rotting rags, which it resembles, been superseded by boiling in rotaries.

After having been boiled with caustic soda, the waste is at present washed in an engine and emptied into drainers. In some mills it is taken from the drainers and dried in a centrifugal cloth-wringer, of the kind shown in Fig. 43.

The bands of dry pulp which the latter furnishes, are passed through a picker, which tears them into shreds, and then put a second time into a rotary boiler, where they are this time probably treated with lime. After this second boiling the waste is ready to be bleached in the engine, or, as is done in one prominent mill, with chlorine gas.

The quantity of paper, yielded by cotton waste, varies from 30 to 50 per cent., according to its quality and treatment. Excellent blotting-paper is made of it, and we have seen very good surface-sized flat-cap, of which it formed the principal part.

SECTION VII.

Boards.

265. Binders' Boards.—Boards are used in large quantities by bookbinders, but their appearance is entirely changed, before they go forth as book covers from their workshops. Fine paper or cloth is pasted on their surface, and the color of the original boards cannot be seen.

It is, therefore, indifferent what stock these boards are made of, provided they be thick, strong, and stiff; the waste of other mills, waste paper, clay, and other cheap materials, enter largely into board-pulp. Bagging or rope serves as hard-stock, and the whole mass is simply beaten in the engine and emptied into stuff-chests.

The machine on which boards are nearly altogether made in this country, is the first part of a cylinder machine, represented by Figs. 92 and 93. The upper press-roll is of wood, instead of iron; its circumference must be of exactly the length of one or two boards, and two grooves pointing to the axe, and parallel with it, divide it in halves. The wet paper, coming from the cylinder, is allowed to wind up on this roll, until it has the thickness required for the boards.

Every additional layer of paper which is wound up, interposes the thickness of one sheet between the two rolls, and raises the upper one as much, until it has ascended high enough to reach with the top part a small iron roll, which is connected by means of a spring with a little bell, thus causing the latter to ring until the attendant has removed the boards, and the roll has sunk back to its original position. This simple piece of mechanism is fastened to one of the side-frames in such a position that the small iron roll (of about 3 inches diameter and $\frac{1}{2}$ inch face) comes in contact with the press-roll only near one of the ends, which is never occupied by the boards, and the thickness of the boards can be regulated by setting the fork, in which the small roll is suspended, higher or lower, and holding it with a set-screw.

As soon as the ringing of the bell indicates that the boards have reached the required thickness, an attendant (usually a boy) passes a knife through the grooves all across the roll. The knife, being thus guided, cannot fail to cut the boards square, and, after having passed through the press again, the latter are easily taken off and spread flat on a table. This table is fastened to the frames at about the height of the top of the lower press-roll, and as near to it as possible.

One machine of this kind can furnish from 1 to 2 tons of boards in twenty-four hours, according to its width.

The wet boards are in most cases dried in the open air by being simply laid out on a grass-plot—a system which may answer for small mills, but which is not reliable

enough for larger establishments, where the large amount of labor and capital employed cannot be permitted to be dependent on the weather.

266. W. O. Davey & Sons' Board-Mill.—This establishment is situated on Jersey City Heights, opposite New York City; it is believed to be the largest manufactory of binders' boards in this country—perhaps in the world—and the superiority of its products is proved by the fact that they are always in demand at the highest market price, and preferred to ordinary or *country-made* boards, even at an advance of from 25 to 50 per cent.

The proprietors have, with commendable liberality, given to the author an opportunity of investigating personally their process of manufacturing, of which a description will be found in the following lines:

The mill is driven by steam-power only, and receives its whole supply of water from the Jersey City water-works.

The refuse of the oakum factory, which forms part of the establishment, and tarred ropes, which cannot otherwise be utilized, make up the hard-stock.

The ropes are cut into small pieces in a machine which is in every respect like those used in machine-shops for cutting sheet iron. A stationary knife, about one foot wide, is fastened upright in a solid cast-iron frame, and another similar knife moves up and down and meets it like scissors.

As a general rule, the raw materials, tarred or untarred, are furnished to the engines in their original state, without having been subjected to any boiling; the expense of that operation, as well as the unavoidable loss of fibres connected with it, being saved, because it is not necessary that the fibres should be extracted perfectly pure.

Some ropes are, however, so hard that they cannot be reduced in the engine without having previously been softened, and they are boiled in a rotary with lime and with the waste-water from the board-machines, which has for this purpose been pumped into receivers in the upper part of the mill. The tar, with which many of the ropes are impregnated, is rather desirable than objectionable.

Waste-paper and boards of the lowest grades, previously soaked, but not boiled, in water, form a portion of the stock; they are furnished to the beaters with the ropes and ground into pulp.

The stock is not washed in the engines, but only ground on solid elbow-plates, which are set in an improved manner. A patent for this improvement was granted, on September 5th, 1871, to Edward Wilkinson, of Paterson, who assigned it to W. O. Davey & Sons; and the following extract from the patent-specifications, with the Figs. 126 and 127, explains the invention:

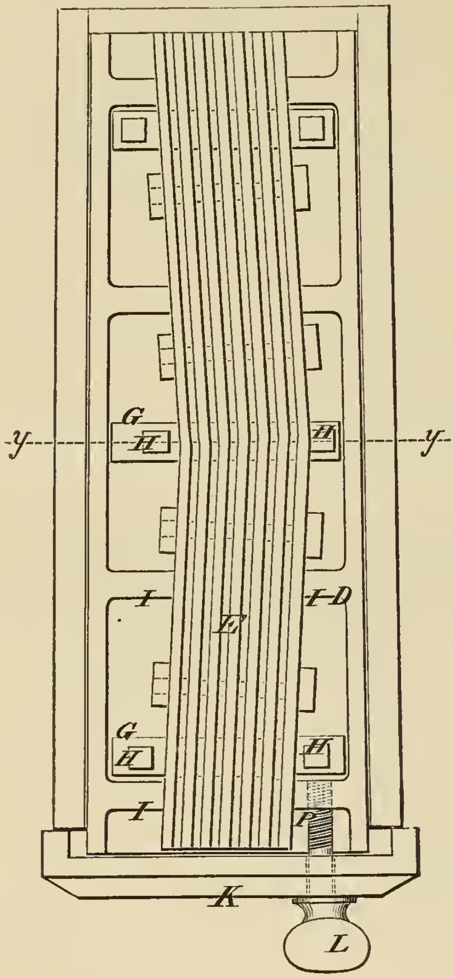
"Fig. 126 is a plan view of my improved apparatus, and Fig. 127 is a transverse section on the line *y y* of Fig. 126.

"Similar letters of reference indicate corresponding parts.

"I propose to have a metal box A fitted in the bed-frame B of the engine immediately under the cylinder, which is indicated by the dotted line C, for holding the case D in which the cutters E are confined, the sides of said box being slightly wider apart at one end and bottom than at the other end

and top, so that the case D, which is correspondingly fitted, will wedge in tight when shoved in snugly from one end. The cutters are fitted to bars G placed in the bottom of case D transversely, and having temper-screws H screwing through them down upon the bottom of the case to raise or lower them. The cutters are also confined between the cross-bars I, which hold them to the work while being adjusted up or down. This arrangement admits of applying a set of cutters and removing them in the most ready manner, so that but little time need be lost, as in the case with the rude apparatus heretofore used, which requires many hours of laborious work to shift and adjust the cutters. I propose to employ two or more cases D and sets of knives, so that when one set gets dull and is taken out another can be readily put in. If the case D be difficult to start when wedged in, a bar K and screw L may be employed for the purpose, the screw passing through the said bar, which is placed against the end of box A and screwing into case D."

Fig. 126.



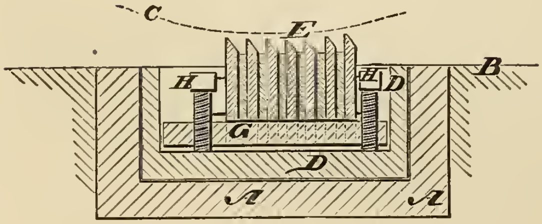


Fig. 127.

Messrs. W. O. Davey & Sons make both the outer stationary box and the inner movable one of cast iron; they use blocks of the ordinary elbow-plates, in which the channels for the reception of the cross-bars G are planed out, while the ribs I of the case D are cut so that the plates will fit exactly into the openings.

The advantages gained by this arrangement are:

Quick and easy exchange of the plates, as claimed in the specifications, and the certainty that they will always occupy the same position.

The facility with which the plates can be set higher up when worn down, by means of the screws H H.

Wooden keys or boards are usually placed under the plates when it becomes necessary to raise them; and it is claimed by the inventor that the latter may, owing to the elasticity of the wood, have a very slight up and down movement, while the use of the rigid iron screws H excludes this possibility.

The engines are emptied into stuff-chests, which supply three cylinder-machines, on which the pulp is transformed into boards of almost any thickness. These ma-

chines differ from those described in the preceding article 265 only by having, in the place of a fan-pump, a lifter-wheel, the buckets of which are filled while passing through a trough wherein the lower part of the wheel is immersed, and discharged into a spout, from which the water returns to the vat and screen.

These wheels move slowly, require little power, and, being open and accessible in all their parts, cannot be obstructed like fan-pumps; but they will not remove the water from the interior of the forming-cylinder so fast, and consequently not keep it so low as the latter.

The wet boards are by artificial means deprived of the larger portion of their water, and the balance only is evaporated in the open air, or by warm air under cover.

When first taken from the machine, the boards are set up in straight piles, alternating with one sheet of felt for every two, three, or four boards—according to their thickness—on the platform of a hydraulic press.

The pressure applied to this pile is increased as long as considerable quantities of water escape, but not sufficiently to crush the boards, the operation lasting altogether but from five to ten minutes. They are next put into a heater, the construction of which will be understood from the following description:

About twenty flat, hollow plates, formed of two sheets of iron or copper, about 2 feet by 10 wide, and joined together at the edges, are placed in a horizontal position above each other, like the steps of a stairway, leaving less than 2 inches space between them, and projecting beyond the next plate above about 2 inches.

Exhausted steam from the engine enters each of these hollow plates at one of the back side corners, and leaves at the other corner on the same side.

The short pieces of pipe, through which the steam enters and departs, rest on iron frames, and serve as journals, on which the hollow plates can be turned up and laid back like the leaves of a book. The movable joints between these inlet and outlet pipes and the stationary ones, which bring the steam and carry it off, consist of short pieces of rubber hose, slipped over the corresponding ends of both.

The sheets are not flat; their surfaces are covered with numerous cavities like those of the heaters in dwellings, which not only increase their heating capacity, but also prevent the adhesion of the boards.

While the heater is empty, the plates are turned up a little more than a quarter of a circle, reclining in a nearly upright position against the frame, but when boards are to be dried, and some have been spread on the lowest plate, the next plate is turned down to its horizontal position; boards are spread on it, and so on until all the plates are laid down and covered with boards. Steam is then admitted during more or less time, according to the thickness of the boards, until they have been sufficiently dried. After less than one hour the steam is usually turned off, the leaves are opened again, and the boards removed.

Four such heaters are used for the product of the three board-machines.

If the boards were allowed to dry hard, they would become blistered; they are therefore removed while yet moist, as soon as they are able to carry their own weight,

or to retain their form without support, and in summer-time they are spread on a grass-plot near the mill. Less than one day of such exposure will be sufficient to dry them if the weather is favorable.

A large drying-house is also provided, which takes the place of the grass-plot in bad weather and especially during winter.

The lower floor is partly occupied by the steam-boilers, and not far above them a framework of strips of wood or lath fills the whole space between the four walls. Another framework of the same construction forms a second story about 6 feet higher up.

They are both strong enough to carry the weight of the men who walk over them, although they consist of no more wood than is necessary for the suspension of the boards.

The roof is supplied with ventilators for the escape of the moist air. If the drying-room is uniformly heated, as it should be, the air, which is loaded with moisture, being heavier, will sink to the bottom, while the dry air rises to the top, and escapes through the ventilators. From this it follows that no air should be allowed to escape from the top, but that it should be carried off from the lowest parts of drying-rooms through wide chimneys or spouts, which reach down nearly to the floor. The superintendent, Mr. Meyers, has tested this in an experimental way by using a pipe instead of a chimney, and found the theory confirmed by the issue at the upper end of air which was saturated with water to such an extent that it appeared like a dense vapor.

Hooks of galvanized iron, with pointed ends, like the *tenter-hooks* used in woollen mills, are driven into the strips of wood or lath, and the boards are hung up on them by one corner.

As the radiation from the steam-boilers does not furnish sufficient heat, an additional supply is provided by wrought-iron steam pipes, many rows of which line the walls of the building.

It would be preferable to dispense with the grass-plot, and dry the boards by steam during the whole year, but as a temperature of about 100 degrees is kept up in the drying-house, this would be too severe on the operatives during the hot summer days, when open air drying is for this reason resorted to.

The boards, after having been dried in the air or above the boilers, are ready to be calendered.

The production of the whole mill, or about four tons of boards per day, are finished with one pair of hollow chilled rolls of about 15 inches in diameter, the lower one of which is driven by spur-wheels. Steam is admitted through the journals of both rolls, and the boards are passed through as often as is necessary in order to give them a good surface, one or two passages only being usually required.

This process of calendering resembles somewhat the work of a laundry; as it is indispensable there that the irons should be heated to a certain degree in order to put a good surface on the linen, so must the calender rolls be heated to a certain degree if the boards are to be well finished.

The rolls, just described, are cast full; holes of 3-inch diameter are bored

through their centres, and the steam enters and leaves through the journal on the front side; but it is the superintendent's opinion that it would be preferable if the steam were introduced through one journal, and taken off through the other one, as the rolls could then probably be heated to a higher temperature.

To facilitate the action of the calenders the boards are, before being passed through them, exposed to the influence of steam, until their surfaces have been softened enough to be more susceptible to the pressure of the rolls, one minute of such exposure being frequently quite sufficient. They are to that end set upright on their edges in an oblong iron box, provided with a false bottom, composed of wooden slats, below which steam is introduced as soon as the box has been filled and the cover closed.

The steam-drying apparatus used at this mill and described in the foregoing lines, although made of iron instead of copper sheets, causes a great deal of expense. The movement of the plates up and down produces a heavy strain near the edges around which they turn, and they soon wear out and crack in those places. If once broken they are useless, as they cannot be patched well enough to give satisfaction. The rubber hose which forms the turning-joints requires frequent renewal, and is another source of expense. Different modes of construction have been tried, none of which have given as much satisfaction as the one which is used at present; but we have no doubt that it can and will be improved upon in the future. All the steam which escapes from the engine, is consumed in these dryers.

Very little of the raw material is wasted, as it undergoes no washing-operation.

267. Press-Boards.—Press-boards, glazed boards, fullers' boards, and pattern boards are names which indicate the various uses made of them; they are much thinner than binders' boards, but tough and strong, and present a highly-polished glass-like appearance.

Any stock which produces good manilla paper may be used for press-boards, and they are like other boards made on cylinders, and taken wet from the upper press-roll.

Being less heavy and more pliable they can be more easily dried than binders' boards. We have seen a cast-iron drying cylinder of about 10 feet diameter used for this purpose. A canvas felt covers its entire drying surface, with the exception of a short open space at a convenient height from the floor, where the boards are passed under it, and taken off after they have made a sufficient number of revolutions with the cylinder to be in the desired state of dryness, the open space not being wide enough to permit them to drop off without assistance. The surface of this cylinder is not much curved for the length of one board, and does not bend it sufficiently to injure it.

Press-boards must be polished until their surfaces become perfectly glassy and reflect the light. We have seen it done in a new mill very effectually by means of a chilled iron or steel roll of about 10 inches in diameter and 2 inches face. This roll forms the lower end of a heavy wooden pendulum of about 10 feet in length, and irons the board under it by bearing on it with all the weight of the pendulum, while it is swung or rolled over it by means of a crank and a wooden connecting lever. The

wooden platform, on which the boards are spread, is cut out in a circle, the centre of which is the axis at the upper end of the pendulum around which it swings. This excavation is several feet long, and covered with a steel plate, over which the boards are gradually pushed by a female attendant, until they are thoroughly polished by the roll, a more or less glazed surface being obtained by moving the boards through, slower or faster.

This is a rather primitive and old system of calendering, but the boards glazed by it are of excellent quality. Good calenders constructed of chilled rolls and heated with steam, would, however, do the same work with less labor and time.

268. **Straw Boards.**—Straw boards have within late years found many new applications, and their consumption has increased to such an extent, that a number of special straw-board mills have been built, and are fully occupied. They were formerly made, like rag boards, on cylinder machines, and dried in the open air, but this system is now replaced by machines, on which the straw boards are formed, dried, and cut like ordinary paper. Cylinder machines, with from two to six forming-cylinders, have been used for this purpose, but they are at present superseded by Fourdrinier machines.

To make very thick boards, every device by which water can be extracted from the paper, while it is being formed, has to be used. The wire must be long and supplied with good suction-boxes, and the first press must be furnished with two wet-felts, one running as usual over the lower roll and carrying the web, and the other surrounding the upper roll, so that water may be pressed out from the upper as well as from the lower side. The upper felt runs through a wash-box, upon which several pairs of wooden rolls are mounted, and, being alternately soaked in water and squeezed by the rolls, is kept so clean that it may remain at work for weeks without ever being removed for the purpose of washing, like other wet-felts. The application of this felt and wash-box is covered by a patent, issued in 1865, to Scanlen, Stine & Ross, and it is believed that machine-dried straw-boards cannot be made without it.

The drying part consists usually of from twelve to twenty 3-feet cylinders, disposed in two tiers, and a machine of this kind can produce straw boards of nearly $\frac{1}{8}$ inch thickness, and in quantities of from four to eight tons in twenty-four hours.

The straw is boiled—in the same manner as for ordinary straw wrapping-paper—with lime, in open tubs, and taken out by manual labor. Hoisting arrangements have been tried and again abandoned, because it is considered more advantageous, to wash the straw and deprive it of the larger part of the lime while it is taken from the tubs with hooks, than to economize some of the labor.

Large quantities of straw boards, covered with white or colored paper, are used for paper boxes, and some manufacturers now line the boards, while they are running over the paper-machine, by means of B. F. Fields's patent lining-attachment.

It consists of a number of rolls, by which paste—taken from a box which forms part of the apparatus—is applied to the lower side of a web of white or colored paper, as it is wound from a reel-shaft and conducted to the dryers. These dryers, nineteen in number, are disposed in two tiers, the web of boards passing alternately over a

lower and an upper one. The upper cylinders are, however, not supplied with a felt, which would prevent the paper from joining the boards while they are passing over them. A platform is erected above the dryer preceding the last one of the upper tier, and a boy attendant, who is stationed there, takes the lining from the pasting apparatus—which is situated above the machine, but within his reach—and presses it upon the web of boards until it adheres sufficiently to be pulled through without further assistance. The boards and the lining travel thus together over the last three cylinders, where they are well dried and united. Two rolls of paper are always supplied to this attachment, so that a new one can be started without loss of time as soon as one is wound off.

Numerous pasting machines for separate boards as well as for rolls have been invented and patented, but they do not come strictly within the range of this book.

As an example of the numerous fields of industry, in which straw-boards will probably be used in the future, we will only mention railroad car-wheels, and quote an article on this subject from the Philadelphia *Press*, February 7th, 1873:

"It is stated that a Connecticut railroad is about to make a trial of the so-called paper car-wheels. These wheels are costly, but run safely and easily; they have been known some time to car-builders, but their introduction into general use has been prevented by the expense. Sheets of common straw-paper (boards) are forced into a compact mass by a pressure of 350 tons. The mass of paper is turned perfectly round, and by a pressure of 25 tons a hub is forced into a hole in the centre. This paper-wheel, by a pressure of 250 tons, is next forced into a steel tire with $\frac{1}{4}$-inch bevel upon its inner circumference. Two circular iron plates are then bolted on to the tire to keep the paper filling in place. By this arrangement the steel tire rests upon the paper only, and partakes of its elasticity. It is claimed that these wheels wear longer than those of any other description, injure the tracks less, and run with less noise."

269. Leather Boards.—A very hard variety of boards is manufactured partly from leather clippings. The leather is for this purpose cut into small pieces like rags, reduced in the engine with about the same quantity of bagging and waste paper, and made into boards on a cylinder in the ordinary manner. If the pulp has been properly treated in the engine, and especially if the boards have been well calendered, they acquire to some extent the appearance, and even some of the qualities of leather.

Piette recommends that the leather, after it has been sorted, cleaned, and passed through a rag-cutter, be filled in baskets or bags, and suspended for about a week in the water of a river, until even the hardest black leather has been thoroughly soaked; it is thereby not only washed, but also softened, and can the more easily be reduced in the engine; and to complete the operation, this bath is to be followed by a second immersion for twenty-four hours in a tub filled with lukewarm water, made slightly alkaline with soda or lime. This process would probably be found too slow, and might be carried out more quickly, and with equally good effect, in some washing-machine.

Leather requires considerable time for washing and grinding, and must be frequently stirred with a paddle to prevent it from settling on the bottom of the engine.

Sizing can be dispensed with, as the leather contains large quantities of gelatine.

SECTION VIII.

Roofing, and Building-Paper.

270. Roofing Paper.—The roofs of buildings are frequently covered with paper which has previously been impregnated with tar, and thus made water-tight.

The stock used in the composition of the paper must be of a porous nature, as its quality depends principally on the quantity of coal-tar or of a similar substance which it can absorb. The pulp is, therefore, made up principally of woollen rags, mixed with a sufficient quantity of hard stock to give it the necessary strength. Blown cane fibre has also been found to improve the quality of roofing paper.

It is made on cylinder as well as on Fourdrinier machines.

271. Building Paper or Building Boards.—It is well known that paper is a very bad conductor of heat, and if applied to buildings, will prevent the outside cold or heat from communicating through it with the interior.

The walls of a great many dwelling-houses in the United States are therefore covered with paper boards either inside or out; they are especially useful for light frame buildings, to the outside of which they are nailed, and then covered by wooden weather-boards, or by an additional brick wall. They are also put on the inside of dwellings instead of plaster, and their usefulness for this purpose was exemplified in 1871, when the Rock River Paper Company papered, immediately after the Chicago fire, 10,000 houses, at a cost of $5 per house. These dwellings (16 by 20 feet), each one of which was built in one day, provided speedy shelter for the thousands of homeless inhabitants.

The principal raw material of which they are manufactured, is straw, usually mixed with some of the lowest grades of rags, waste paper, cane fibre, and with a variety of chemicals, the application of which to building boards, in many cases protected by patents, has mostly for its object to make the boards water or fire-proof, or both.

Building boards are made on double-cylinder or Fourdrinier machines, and sold in rolls like hanging and roofing paper, and although a comparatively new article, they are not only already used in large quantities, especially in the Western States, but promise to give employment to many additional paper-mills.

SECTION IX.

PARCHMENT-PAPER.

272. Use and Preparation.—It has been found that unsized rag-paper or cellulose changes its nature, if it is for a short time immersed in diluted sulphuric acid and then again well washed; it becomes tough, water-tight, and transparent, like animal parchment.

This discovery has been utilized in Europe, where the vegetable parchment is produced in endless rolls and largely used: the druggists tie it over bottles whenever they must be hermetically closed; envelopes for the transportation by mail of valuable papers and money are made of it; parchment goblets filled with water, beer, or wine, are sold to travellers on the railroads, &c.

The mixture of sulphuric acid and water, as generally used for the manufacture of parchment, consists of 2 volumes of acid (SO_3,HO) and 1 volume of water at 60 degrees Fahrenheit; the paper is subjected to its influence for a sufficient time to be parchmented to the desired degree, then again washed with water, and lastly with ammonia, to neutralize any remaining traces of acid.

If the paper is rolled up on a reel and slowly conducted through a trough with the acid bath, then through other troughs containing water and ammonia, and lastly, over a set of dryers, an endless sheet of parchment can be made.

To explain its nature and formation, we cannot do better than to reproduce here an article written in German by T. Ferwer, and translated by J. H. Tieman, for the *Paper-Trade Reporter*, No. 19:

"The only account we have, so far, in relation to the chemical composition of vegetable parchment is from Prof. A. W. Hoffman. According to his views, the action of the sulphuric acid causes a new arrangement of the molecules, thereby changing the paper into a new substance, with entirely new properties. I have for a long time doubted the correctness of this theory. Experiments showed me that the vegetable parchment is an unchanged paper in which the fibres are united by a small quantity of a substance, formed by the action of dilute sulphuric acid on the plant fibres, supposed by some chemists to be pure cellulose, and by others to be a middle substance between starch and cellulose, and called amyloid.

"In order to make this amyloid, which thus far is only interesting from a scientific point of view, 30 parts by weight of dilute sulphuric acid (4 parts acid to 1 part water) are added to 1 part of loose cotton; the latter dissolves readily in the acid, and in about thirty seconds forms a stiff, gelatinous mixture, which gradually becomes more liquid, and in about fifteen minutes becomes of the consistency of sugar syrup. When this mass is mixed with water, a white, flocculent, gelatinous mass separates, in which the structure of the cotton can no longer be recognized. If the acid mixture be allowed to remain quietly for some time, it changes gradually into dextrin and sugar, so that after seven or eight

hours, if water be added, but a very small quantity of the flocculent mass separates. Amyloid comforts itself with acids, alkalies, chloride of zinc, &c., the same as ordinary plant fibre, and is only distinguished from it by its shapelessness, and also that when colored blue by iodine, it may be decolorized by simply washing with water, which is not the case with starch.

"In combination with sufficient water, amyloid has a pasty appearance; when spread upon glass it dries to a thin, transparent, tenacious skin. When dried on paper it is not so adherent, and may be easily removed after drying. When, however, the amyloid is precipitated from its solution directly on to the paper, as occurs in the formation of vegetable parchment, it remains inseparably united with the fibres.

"Under the microscope, a piece of vegetable parchment shows the fibres distinctly, surrounded by a thin, transparent skin. That the fibres have been acted on by the acid and surrounded by a coating of amyloid, there can be no doubt; iodine solution turns them blue; but this change is only on the surface, for even the fine fibres of flax, when in the paper, retain their form unaltered.

"Having now considered the composition of vegetable parchment, the formation of the same is readily followed.

"When unsized paper is dipped into dilute sulphuric acid, at ordinary temperature, a gelatinous coating is instantly formed on the surface, and the same thing occurs to the surface of the fibres in the interior of the paper as soon as the acid penetrates to them. If the paper is now taken out of the acid and dipped in water to which ammonia or caustic soda has been added, the further action of the acid is suspended, and at the same time the acid compound is resolved into amyloid and sulphuric acid; the former adheres to the fibres and the latter is removed by washing in water. By drying the paper, the fibres unite with the amyloid to a dense mass, which is parchment-paper. The adhesion of the fibres during the drying is greatly assisted by the gelatinous covering on the surface of the paper, which readily admits the escape of the vapor from the interior, and prevents the admission of the air which would otherwise replace the escaping moisture. This is also the cause of the shrinking, crumbling, and transparency of the parchment.

"It is thus seen that in order to make a dense and firm parchment it is necessary to avoid everything which would cause more than a superficial change of the fibres; especially must the use of porous paper be avoided, for, though it might yield a dense parchment, it could not be a firm product. Ordinary cotton, flax, and hemp rags are too porous to be changed into parchment. A firm, thin cotton thread, treated with sulphuric acid, makes a much stronger substance than a thread twice as thick if loosely wound. A thin, dense, cotton stuff, when pressed before being treated, in order to bring the fibres into as close contact as possible, yields a substance of extraordinary firmness, which may in many cases be substituted for thin leather. When softened by rubbing with fat, it could be used very extensively."

Alexander T. Sheldon has received a patent of invention for an improvement, which consists in passing the paper first through a bath of alum, then through another one of concentrated sulphuric acid, and lastly through water, &c. The alum coats both sides of the paper, and the concentrated acid acts so quickly that only the surfaces of the paper will be changed, while the body remains intact. The object is to preserve the pliability, opacity, and other good qualities of the paper, while it is at the same time made water-tight.

More or less parchmented paper will certainly find many useful applications if it is once introduced and manufactured on a large scale.

Chapter VI.

GENERAL REMARKS UPON WASH-WATER, POWER, CONSTRUCTION, LOCATION, CAPITAL, MANAGEMENT, AND STATISTICS OF PAPER-MILLS.

SECTION I.

Wash-Water.

273. Its Importance.—The water which is used for the preparation of the pulp, especially for washing purposes, is called *wash-water*, in contradistinction to that which only drives water-wheels and produces power.

To perceive its great importance we need only consider the quantity which is necessary to wash from 400 to 500 pounds of rags in an engine. If the engine is, for example, 15 feet long, $7\frac{1}{2}$ feet wide, and filled about 2 feet high, it will hold, taking the round ends, backfall, &c., into consideration, about 160 cubic feet or 1200 gallons, or about 10,000 pounds of water—that is, about twenty times the weight of rags. If enough water is used during the operation of washing to fill the engine five times, the 500 pounds of rags will be brought in contact with 6000 gallons, or one hundred times their own weight of water.

This quantity may yet be considerably increased, perhaps doubled, if we add the water which is used in boiling, bleaching, and on the paper-machine.

Every pound of rags is therefore liable to be soiled during its transformation into white paper by the impurities contained in 100 to 200 pounds, or in 12 to 24 gallons of water.

These impurities are of two kinds: those which are only suspended, floating, or *mechanically* mixed, and others fully dissolved. In most cases the latter cannot be seen, and, to make a distinction, may be called *chemical* impurities.

274. Mechanical Impurities.—If a river or a creek flows through soil composed of clay or any other soft material, it will be clear as long as nothing disturbs its quiet and even flow; but as soon as rain falls, some of the infinitely small and light components of the earth are bodily carried along by it, and the stream begins to look colored and dirty. All these mechanical impurities are visible separate bodies, and settle on the bottom if they have time and tranquillity so to do.

Mills which use surface streams as wash-water should therefore be supplied with artificial lakes or settling ponds, of as large dimensions as the locality will permit.

The water is admitted into these reservoirs when it is clear and shut off when muddy; they must therefore be large enough to hold many days' supply.

If a large settling pond cannot be had, the mechanical impurities must be separated by filtration. The cheapest and most permanent materials for filters are gravel and sand. They are hard, principally quartz, and their round form prevents them from forming a mass so compact that water cannot pass through, while they present at the same time a very large surface for the deposition of impurities.

The filters may be built of brick or stone and cement, or simply of earth; their bottoms, according to Planche, are to be covered with coarse gravel or stone, ordinary gravel succeeding, and sand forming the upper layer. The water usually enters on top and leaves at the bottom. In the course of time such an amount of dirt will settle on the stones that water can no longer be purified by passing through them, and then they have to be thoroughly washed.

To suffer no delay the mill should be supplied with two such filters, or with one divided by a partition, which may be opened or closed at will, so that one part can be cleaned while the other is yet in operation.

A paper-mill in Prussia, which the author formerly superintended, has a square brick filter, divided by cross walls into four equal compartments, which are filled several feet deep with fine gravel, and connected by short pieces of large iron pipes in such a manner, that the water passes constantly through three of them in succession, while one can be cut off and washed out. A workman enters for this purpose, moves the gravel to one side, thus making an empty space, on which he gradually washes the gravel by mixing it with plenty of water. The dirty water escapes through a valve with which each chamber is provided.

The wash-water frequently passes through additional strainers before entering the reservoir in the upper part of the mill. One, which is frequently seen, consists of two wire-cloth covered frames, with woollen rags, slightly cut in the engine, filled in between them.

This double frame is fastened horizonially in a tub or vat, the water passing through it from the lower side, so that the impurities cannot lodge upon it, but will fall to the bottom and leave the wire unobstructed.

If the water enters the engine from the top, a flannel bag may be tied around the outlet of the pipe, and, if frequently washed out, it will be of some assistance.

The following Fig. 128 represents a section of a patent filter, which is seen in many of our best New England paper-mills. A brass or copper cylinder is divided into three parts by plates or diaphragms A and B of the same diameter, to which small cylinders or pockets C, covered at both ends with wire-cloth, and filled with pieces of sponge, are fastened. The water, entering from below (or above), passes through the pockets C, where the sponge retains the impurities, and leaves at the other end. The narrow projecting rings D prevent the water from making its way along the sides without penetrating through the sponge.

The capacity of the apparatus depends evidently on the number and size of

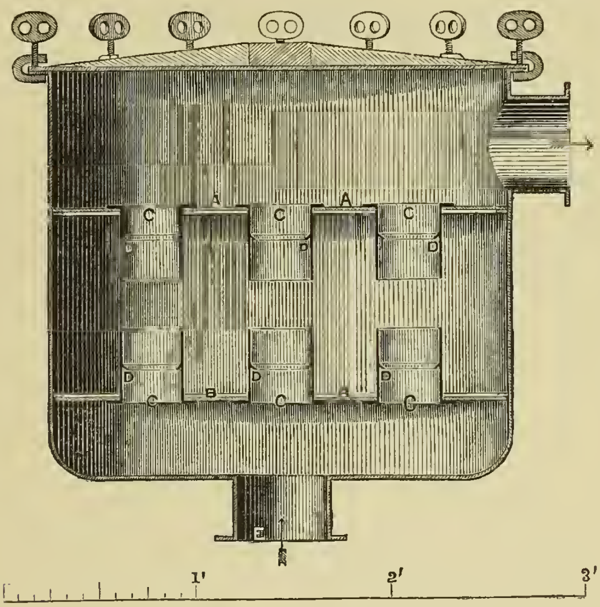
the pockets, and as many of them as room can be found for, should therefore be fastened to the plates A and B.

A valve is bolted to the inlet E, and regulates the flow of water.

Every beating-engine is, in some mills, supplied with one of these filters; while all the wash-water passes in others through one or several large-sized ones directly on leaving the reservoir.

Simple as these filters are, it requires experience and judgment to keep them in order. The sponges must be frequently taken out to be washed, and then put back

Fig. 128.



into the pockets; if they be packed in too tight, a sufficient quantity of water cannot get through, but on the other hand the water will not be purified if they are laid in too loosely.

275. Chemical Impurities.—The chemical impurities, mostly invisible, are as numerous as the materials over which the streams pass in their courses. Some metals, but especially iron, some of the alkalies, principally lime, and extracts of decaying vegetable matter from the drainage of cultivated fields, are the substances which are mostly found dissolved in water.

Carbonates of lime and magnesia are very slightly soluble in pure water, but dissolve freely in water which contains carbonic acid, and as the latter is always to some extent absorbed from the air, the water is capable of holding some carbonate of lime or magnesia in solution.

Sulphate of lime or gypsum is another form under which this alkali is found in water.

Common salt or chloride of sodium appears occasionally.

Water which contains much lime or magnesia is called *hard*, and every housekeeper knows that it will not answer for washing purposes, as it does not dissolve soap until the lime or magnesia has been precipitated.

If the carbonic acid, which enables the water to hold the carbonates of lime and magnesia in solution, is driven out by boiling, or absorbed by caustic lime or soda which may have been added for this purpose, the carbonates will assume a solid form, settle to the bottom, and thus render the water soft. The sulphate of lime or gypsum, or the chlorides or nitrate of lime, cannot be so easily eliminated, and water which contains considerable proportions of them is therefore called *permanently hard.*

Hard water also affects a good many coloring materials, and its most objectionable quality is that it forms deposits in steam-boilers, which are frequently very troublesome, and may be the primary cause of an explosion.

Wash-water which contains a sufficient quantity of lime to be hard, is unfit for a paper-mill.

Iron salts in contact with alkalies, lime, or soda, deliver their acid to the latter, and the iron precipitates as oxide or rust, coloring the pulp until it may be re-dissolved by sulphuric or other acids. Although the proportion of these salts be insignificant, the quantities of water used are so enormous that the total amount of iron is yet quite considerable. A 500-pound engine, for example, carries about 10,000 pounds of water, and if this contains only one-fiftieth of one per cent. of iron, there will be 2 pounds of it in the whole mass, and if this water is renewed five times during one washing operation, 10 pounds of iron will be brought in contact with the rags.

The soda, bleach-liquor, alum, or sulphuric acid, absorbed or neutralized by these iron salts in the multitude of operations, in all of which water is an important factor, sum up to a large quantity in a short time. It is quite probable that the difference in the quantities of chemicals, consumed for like operations on the same stock in different mills, may sometimes be traced to this source.

The presence of iron can easily be discovered by the addition of a solution of yellow prussiate of potash to the water; the iron salts will form with it Prussian blue.

The total amount of mineral impurities can be ascertained by evaporating carefully several gallons of water and weighing the residue.

The Croton water, which supplies New York City, is considered very pure, and contains 10.93 grains of solid matter in a gallon, or about one-fiftieth of one per cent.

For papers of a lower grade, such as wrapping, the preparation of which requires few chemicals, it is not a matter of vital importance; but as the color of all white papers depends greatly on the purity of the wash-water, an abundance of pure, clear, wash-water is one of the conditions of the successful manufacture of fine papers.

276. Sources of Wash-Water.—To determine which are the best sources for good wash-water, it is necessary to understand the manner of their formation.

The water which covers the surface of the earth, changes its form constantly; it evaporates, and is taken up and carried away by the winds as vapor. The air is able

to hold more water at a higher temperature than at a lower one; any cold wind will, therefore, cause some of it to drop in the form of rain or snow.

The water, on returning to the earth in this form, is as pure as it can be found in nature; it contains no foreign matters but the gases which it takes up in the atmosphere, and if it flows over hard, insoluble substances, such as rocks of granite, or quartz, or over sand, it preserves this purity. Streams of this kind are very valuable, but unfortunately they can only be found in the mountains, in most cases too far from markets, to be available.

The purity of all surface waters, such as creeks and rivers, depends entirely on the nature of the soil over which they themselves and their tributaries pass, and should be in every case investigated.

A great portion of the snow and rain filters through the ground and comes again to the surface in some lower places, as springs, or gathers in large cavities below, to which access is had by means of wells.

Very often these underground lakes extend from high places to low ones, and are only prevented from rising to a uniform level by a stratum of water-tight materials. In boring an artesian well this stratum is pierced, and the water forces its way upward with a tendency to reach the level of the highest point of the body of water from which it comes. In some cases it rises through large pipes high enough to drive a water-wheel, while in others it hardly comes to the surface; sometimes the water obtained is very pure, and at others it is loaded with foreign elements.

Boring an artesian well in an untried place is like digging for hidden treasures,—a very uncertain undertaking.

One or more never-failing springs of pure water, furnishing a full supply, are very valuable in a good location.

Where good wells can easily be made, and where experience has shown that they keep their supply all the year, they are, if the water is chemically pure, often preferable to surface water. While the latter may require to be artificially filtered, the well water has been cleared by passing through the soil. This is especially the case in sandy regions, and many cities, for instance Dayton, in Ohio, derive their entire water supply from a single well of large size.

277. Systems of Distribution.—If the wash-water can be taken from a convenient place above the mill, so that it has fall enough to run directly into the engines, a considerable amount of power and some machinery, which would otherwise be necessary to force it up, will be saved.

Mills which are not so fortunate, must have receivers in some of the highest parts of their buildings, into which the water can be lifted by pumps, and from which it is distributed. These reservoirs must be water-tight, and, if of wood, should be circular, but iron is a better material for this purpose, as it does not shrink and open in the joints like wood when for a time empty.

If the pump has to stop for repairs, or from other causes, the mill has to be stopped also, unless the reservoir holds water enough to keep it going.

A strong foundation is at all times required for it, as the weight of water in even a small reservoir is considerable.

One of the largest mills in this country is supplied with a capacious settling pond or reservoir on the top of a hill, situated higher than any part of the machinery, and is filled every Sunday by means of a large force-pump, driven by water-power, with a sufficient supply of water for the six following days.

We have also been informed that two barrels of porous alum are emptied into this pond after it has been filled, in order to precipitate the impurities. The lime and iron, which may be contained in the water in the form of carbonates, will form sulphate of lime and sulphate of iron with the sulphuric acid of the alum, while its other component part, the alumina or clay, is set free and carries down mechanically some of the floating impurities.

278. Quantity Required.—It is impossible to calculate exactly the quantity of wash-water which is required for a paper-mill, but an estimate, on which the sizes of the pump and of the distributing pipes may be based, is indispensable. We shall indicate how the data, on which such an estimate may be based, can be obtained, and coupled with experience, it will be a sufficient guide.

The washing-engines consume by far the larger portion of all the wash-water, and we suppose, for example, that two of them, 15 feet long by $7\frac{1}{2}$ feet wide, holding each about 500 pounds of rags, are used in a mill of a capacity of about 3000 pounds of white paper per day. It is true that they do not always wash at one and the same time, but it happens so sometimes, and we must be prepared in such cases to furnish enough water. If the receiver is large enough to hold all the surplus, so that no water need be wasted through the overflow, no power is lost, but if the receiver is small, the pump has to furnish an excess, which during most of the time runs away.

The washers must be fed with as much water as they are able to discharge, and this will in most cases be amply done by a stream which will fill the empty tub in fifteen or twenty minutes. One of the engines taken for this example, holds about 160 cubic feet $=$ 1200 gallons; two engines, therefore, require in fifteen minutes $2 \times 1200 = 2400$ gallons, or in one minute, 160 gallons.

The quantity of water consumed in boiling, by the beaters, and by the paper-machine, is difficult to estimate, but it is seldom as large as that required by the washers, especially at the high rate, estimated in this example. We are, therefore, pretty safe in taking double the quantity, calculated for the washing-engines, or $2 \times 160 = 320$ gallons per minute, as the whole supply needed.

An abundance of wash-water is one of the first conditions in the manufacture of paper, and it is therefore wise rather to waste power than to have an insufficient quantity of water. We have to make allowance for deficient work of the pump and leakage in many places, and may add one-fourth of the calculated number, or $\frac{320}{4} = 80$ gallons, and thus need a pump, capable of throwing 400 gallons per minute.

The power which is necessary to raise such a quantity of water, can easily be calculated. If it is, for instance, taken from a well, at a depth of 12 feet, and pumped

into a receiver, the water surface of which is 38 feet above the ground, the total height through which it must be raised is $38 + 12 = 50$ feet. It takes as much power to raise the weight of 400 gallons or $400 \times 8\frac{1}{3} = 3330$ pounds 50 feet high, as would be required to raise 3330×50, or 166,500 pounds, one foot high. One horse-power is accepted as equal to the power which is necessary to raise 33,000 pounds one foot high in one minute, and our 166,500 are therefore equal to $\frac{166{,}500}{33{,}000} = 5$ horse-power actual work.

279. Pumps.—Piston or plunger-pumps, with suction or pressure-valves, although the oldest style, are even at present in many cases preferred to all others.

The valves must have time to open and close perfectly if a good result is expected, and their speed should therefore always be moderate.

The perfection of rotary pumps has been the study of numerous mechanics for many years, and the patents taken out for them would alone fill a good-sized book. These pumps work mostly without valves and run fast, but their speed, and with it the quantity of water thrown, can be considerably increased or reduced at will; they take little room, are operated by belts, can be easily set up, and require little care.

Rotary pumps, being generally less efficient as suction than as force-pumps, are usually set as close to the source of supply as possible; some working best, if the water is made to run into them without any suction. As force-pumps they are excellent, and some are even used for steam-fire engines.

The absence of valves makes it possible for pieces of wood, rags, or other solid matters, which may accidentally be in the water, to pass through a rotary, while they would obstruct and perhaps damage a piston-pump. The author found one day some deficiency in the supply of wash-water, when on examination the head and numerous other parts of the body of a snapping-turtle, about 5 inches broad, were found in the receiver. The animal had evidently entered the suction-pipe, was drawn to the (Holly) rotary-pump, and chopped up by it.

The pressure of the atmosphere, at a low density, is equal to that of a column of water of 30 feet height.

If it were possible to construct a pump so perfect, that it could withdraw all the air from the suction-pipe, thus creating an absolute vacuum, the water would rise in it to a height of about 30 feet, forced by the atmosphere outside; but if the water had to be raised but a trifle above this limit, the atmospheric pressure could not do it, and it would never reach the pump. The height to which any pump can raise water by suction is therefore always less than 30 feet.

If the suction-pipe is not perfectly air-tight, if the air enters through a small hole or crack, feeding the pump in the place of water, a vacuum cannot be created, and the pump will run empty. The hole may be small enough to be invisible to the eye; it may accidentally appear by the loosening of a joint, the opening of a sand-hole in the casting, or otherwise, and its discovery is often difficult.

It is most likely to be found by running the pump and creating suction, and

then holding a burning light to all suspected places; wherever there is an opening the current will change the direction of the flame and draw it in.

This difficulty is a sufficient reason for such a disposition, as will admit of as short a suction-pipe as possible.

There is another kind of pump which is frequently used in paper-mills, and recommends itself by reason of its simplicity.

It consists of a strong rubber belt carrying iron or copper buckets, which belt runs over two large flanged pulleys, one of which is located inside of a lower water-tank, while the other is fastened above the upper receiver.

The shaft of the upper roll is turned by a pulley and belt, and raises the buckets which have been filled in the lower tank. They travel up and down in close-fitting wooden spouts or troughs, and are emptied, as soon as they pass over the upper roll, into a receiving channel, which connects with the reservoir.

This pump is built on the same principle as a grain elevator, and works well where the water is not to be raised very high.

SECTION II.

Water-Power.

280. Measuring the Power.—The fall of a body of water, like that of any other substance, exercises a power, equal to its weight multiplied by the height of the fall, and if it is produced by the continuous flow of a stream, it can be utilized.

To find out how much power there is at a given point, it is necessary to establish, by a survey or by levelling, how many feet of fall can be obtained, and what quantity of water flows down the stream during a second or a minute.

It is comparatively easy to measure the fall of water, but more difficult to determine its quantity. The latter is obtained by multiplying the number of square feet of a vertical section of the stream with the velocity, or with the number of feet through which the water advances in one minute. If a race is at hand it may be used for this measurement; otherwise a part of the creek, with as straight banks and as even a width as can be found, should be selected. We measure of it a certain length, say 100 feet, and in several points of this length the vertical section, viz., its width and medium depth. From these several ones the medium size of a section is calculated.

An instrument, resembling a wind-mill on a small scale, has been constructed for the measurement of the velocity of flowing waters, which, when set in a stream at any point, registers the number of revolutions of a fan, which enables us to obtain the speed.

If such an instrument is not to be had, a piece of light wood may be used in its place; it is simply thrown into the middle of the creek, at the point above where the measured part begins, while the time which it consumes in flowing down through the 100 feet length is observed with a watch. The number of feet, made by it in one second, is the velocity, and gives, multiplied by the number of square feet of the medium vertical section, the number of cubic feet of water which pass through the stream in one second.

If a precise calculation is to be made, the speed on the surface cannot be accepted as that of the whole body of water. The friction on the bottom and sides retards the motion, and must be taken into account. If we call the surface velocity per second, found with the floating wood, V, the real velocity v of the stream is expressed, according to the best authorities, by the formula—

$$v = V\frac{7.71 + V}{10.25 + V}$$

If we have, for example, a race or creek of 20 feet medium width, 3 feet medium depth, with a surface velocity of 1 foot per second, the real velocity of the water will be:

$$1\frac{7.71 + 1}{10.25 + 1} = 0.774 \text{ or } \frac{77}{100} \text{ feet,}$$

and the volume of water, which flows through it during one second:

$$20 \times 3 \times \frac{77}{100} = 46.2 \text{ cubic feet.}$$

One cubic foot of water weighs $62\frac{1}{2}$ pounds, and 46.2 cubic feet = 2887.50 pounds. This quantity is available every second, or $60 \times 2887.50 = 173{,}250$ pounds every minute. If there be a fall of 15 feet, the power is equal to the fall of $173{,}250 \times 15 = 2{,}598{,}750$ pounds through one foot per minute.

One-horse power being equal to the fall of 33,000 pounds through one foot height in one minute, the water power amounts to

$$\frac{2{,}598{,}750}{33{,}000} = 78\tfrac{7}{10} \text{ horses.}$$

281. Dams.—The proper construction of a dam depends so much upon the location and the material which can be had for it, that general rules cannot be given. If possible, it should be so situated that a large body of water can be accumulated be-

hind it, which may be drawn upon in dry seasons. Lakes, as sources of supply, are excellent natural reservoirs.

If the dam and the mill are situated in a narrow valley where, in case of a flood, the water cannot spread over a large surface, but is stowed up high, the pressure sometimes becomes so strong that both dam and mill are swept away like chaff before the wind. Such sites on streams, which are subjected to freshets, are dangerous, and require the construction of the best foundations for both mill and dam, which human skill can devise.

The head-race conveys the water from the dam to the point where it begins to act on the mechanism. It may be an open conduit or a closed pipe, or a combination of both. Economy of power requires, that it should be as large as possible; economy of first cost, that it should be as small as possible; the right mean must be chosen. The entrance of the water is regulated by the head gates at the starting-point, while the lower end pours it on a water-wheel or into the penstock of a turbine.

We may also mention in this place the water-power companies, who, by the creation of large powers, have built up some of our most prosperous manufacturing cities, such as Lowell, Lawrence, and Holyoke, in Massachusetts. The latter town especially is considered the principal seat of the manufacture of fine papers in the United States. It is situated on the right bank of the Connecticut River, and has about 12,000 inhabitants. A company was organized about twenty years ago to make the large power of the river available; a dam, over 1000 feet wide and 28 feet high, was built, and the water drawn off by one canal on the Holyoke side and by another on the left bank, at South Hadley Falls. The ground between the canals and the river was laid out in lots, soon began to be occupied by mills of all kinds, and a large town was created where formerly stood only a small village. Nearly 50 tons of paper, principally letter-paper, are at present made daily at Holyoke, and yet a large amount of the 40,000 horse-power which is available, remains to be disposed of at a moderate yearly rental.

Some of the paper-mills obtain their wash-water from artesian wells or through pipes from a distance, and others draw it from the supply-canal through large trunks filled with gravel and built into the embankments.

The success of the Holyoke enterprise stimulated, a few years ago, the formation of a new company for the purpose of utilizing the water-powers of the same Connecticut River, at Turner's Falls, about 30 miles above Holyoke. A dam of about 1000 feet in width was built there, and a number of factories, among which are several paper-mills, are already running, and a town is being built as if by magic.

282. Water-Wheels.—The old-style water-wheel is always vertical, while its more recent competitor, the turbine, is horizontal.

Neither of them, nor any other hydraulic motor, is capable of returning the full actual power of the waterfall.

Vertical water-wheels are divided in undershot, breast, and overshot wheels, according to that part of the circumference where the water strikes them.

The overshot wheel returns the highest proportion of the actual power, while the results obtained with breast-wheels are less favorable, the lower down on their outer circle the water is admitted. The overshot is therefore the only kind of vertical water-wheels which may compete with the turbine as a motor for paper-mills.

If the overshot water-wheel could be constructed so, that the whole body of water would be carried by it from the highest to the lowest point of the available fall, and be there suddenly discharged, nearly the whole natural power would be realized, while, as it is, considerable losses will be suffered, some of which are here indicated.

The fall is represented by the distance between the surfaces of the water in the head-race and in the tail-race. The portion of this distance between the surface in the head-race and the wheel itself acts only by impulse, but not by weight.

Instead of the full outside diameter of the wheel, the distance between the point of gravity of the water in the uppermost and in the lowest bucket must be counted, as it is there where the weight of the water may be considered concentrated. Over half of the depth of two buckets, or the full depth of one bucket, is thus lost.

The wheel must hang free above the water in the tail-race, and the distance between wheel and water, representing a small portion of the fall, is also lost.

The buckets cannot be emptied *suddenly* at the lowest point; they require some—be it never so little—time for it, and must therefore begin to discharge at some height above a portion of the water, the weight of which will be lost for the balance of the fall.

If any water is left in the buckets on their ascent, its dead weight neutralizes the same quantity of live weight on the descending side.

To all the losses just enumerated must be added those from friction and contraction in the races and wheel, from leakage, and bad construction.

To obtain the best possible effect, the wheel must be built in such a manner that no part of it can leak or change position, and its top should be about $2\frac{1}{4}$ feet below the level of the water in the race. Wood will become warped, and will rot, and is therefore inferior to iron; but, if an all iron wheel is too expensive, the buckets alone may be of metal and the body of wood. Care must also be taken to provide an easy escape for the air contained in the buckets, through openings in the sole-plate. A guide-board, over which the water is made to flow in the right direction and to the right spot, is used to convey it from the head-race to the wheel.

The circumference of a water-wheel should, according to the best authorities, have—be its diameter large or small—a speed of not less than 4 feet and not more than 8 feet per second. A point on a large circle, if moving with the same speed as a point on a small one, requires more time to make a revolution than the latter; the larger a water-wheel is, the slower will therefore be the movement of its shaft.

Overshot water-wheels furnish from 60 to 80 per cent. of the natural water-power, according to the amount of care and skill applied to their construction and disposition.

283. Turbines.—The turbine is a horizontal water-wheel with vertical axis, consisting of a drum or annular passage with a set of vanes, curved like the surface of a

screw, so that the water, after having exercised its impulse on them, will glance off with as little energy as possible. While the vertical wheel is moved principally by the weight of the water, the turbine is propelled by its impulse only, and to get the best effect, the water has to be guided so that it will strike every part of the moving vanes as nearly as possible at a right angle.

The first turbine, invented by Fourneyron, was put in operation in the year 1827, at Pont sur l'Ognon, in France; this Fourneyron-wheel was then and is yet constructed of two concentric rings, both of which are open on their vertical sides, closed on their horizontal ones, and supplied with an equal number of vanes. The inner ring is stationary, receiving the water in the centre and acting as a guide only, while the outer one revolves and transmits the power, the water leaving at its circumference.

Jonval made the guide-wheel and the revolving-wheel of the same diameter, and placed them, one on top of the other, in a vertical cylinder. He was thereby able to set the turbine at any height between the head and tail-races, with equally good results, provided that the lower portion, which may be called the suction-pipe or draft-tube, be less than 30 feet high above the level of the tail-race.

To prove this seemingly strange fact, we will take as an example a fall of 20 feet, with a turbine wheel incased in a water-tight cylinder or penstock of 20 feet height. If the wheel is placed at the lowest end, the water is forced through it with the pressure exercised by the 20 feet fall and by the pressure of the atmosphere—equal to 30 feet fall—or altogether by 50 feet. But the atmosphere has also free access to the water in the tail-race, and presses against the turbine with a force, also equal to 30 feet fall, which must be overcome. Deducting, therefore, these 30 feet from the 50 feet pressure from above, leaves only 20 feet or the fall of the water as the active pressure.

If the same turbine is situated in the middle of the penstock, 10 feet from the surface of the water in either race, the water will be forced on to the turbine with a pressure, which is equal to that of the column of water above the wheel, or to 10 feet in addition to the atmospheric pressure, or altogether to $10 + 30 = 40$ feet. But before the atmosphere can in this case exercise any pressure against the wheel from the lower side, it must first overcome the column of 10 feet in the draft-tube below the wheel, and is therefore reduced to 30 less 10 or to 20 feet. The difference between the pressure above and the resistance below is therefore 40 less 20, or 20 feet, as before.

The draft-tube below a turbine acts like the suction-pipe of a pump; if air finds admittance into it, power equal to a fall of the same height is lost.

There is always danger that an opening may be caused by some accident, by faults in the material, or by wear and tear; and even the most insignificant holes, which can hardly be seen, must cause some loss of power. In most cases these pipes are located where it is very difficult to examine them, and much valuable power is often wasted before the faulty spot can be discovered. Suction-pipes or draft-tubes for turbine-wheels should therefore be dispensed with, except in cases where for some reason the wheels cannot be set low enough to do without them.

Some turbines which have within late years been much used, are remarkable especially for simplicity and consequent cheapness. Every opening is provided with a gate, formed and fastened in such a manner, that it serves at the same time as a guide to the entering water. All these gates can be opened and closed by one common rod, with which they are connected by levers or gearings. The water enters on the outer circle and escapes inside, but, instead of running away at once, it passes another set of differently curved vanes, intended to absorb any power which may have been left in it.

These horizontal wheels always run fast, and, like the vertical ones, the more so the smaller they are. They must be made of metal, because wood would take up too much space and could not be moulded into the required shape. The penstock and its enlargement, in which the wheels run, or the casing, is often built of wood; but it is advisable to construct it of iron at all times, especially when it is exposed to the pressure of a high fall. The first expense will be larger, but the almost inevitable escape of water by leakage and the constant repairs of a wooden structure will be avoided.

Turbines lose power, like overshot wheels, by friction and contraction, and because they cannot be constructed sufficiently perfect to absorb all the power. They return from 60 to 80 per cent. of the natural power; 75 per cent. may be considered a very good result, while 80 is only obtained in exceptional cases.

284. Comparative Advantages of Overshot and Turbine Wheels.—Overshot wheels may be used when the available waterfall is such that their diameter will be reasonably large—not below 12 and not above 25 feet; if the diameter would have to be beyond these limits, a turbine would be preferable.

Turbines, being submerged in water, are never frozen up, and although their power will be reduced by backwater in proportion to the diminution of the fall, they cannot be stopped by it like vertical water-wheels.

Large gearing is required, to produce from the slow motion of a vertical water-wheel the high speed required by the line-shaft of a paper-mill, while one pair of comparatively small bevel-wheels only is necessary with the fast-running turbine.

Wherever the supply of water is either abundant or steady, the turbine will give a regular speed and good effect. But it returns the highest percentage of power only with the quantity, for which it has been constructed; and if the supply should decrease and the water fall in the race, the power produced would not only be lessened in proportion to the loss of height and volume, but the percentage obtained from the remaining waterfall would be decreased fearfully. It is therefore imperative to keep the head-race full all the time, and rather to stop and accumulate water than to use it as it comes, in inadequate quantity.

In cases where the water-supply is often insufficient, and where no very large reservoir or pond is at hand, an overshot wheel may be preferable to a turbine, because it will give larger proportions of the natural power with decreasing quantities of water.

SECTION III.

Steam-Boilers.

285. Importance.—Steam-boilers form a very important part of the equipment of a paper-mill, and yet they are sometimes treated with a negligence which is criminal, from the danger to which every person within their reach is exposed.

The consumption of fuel depends so much on the nature, construction, and treatment of the boilers, and is very often so heavy an item in the list of expenses, that too much care cannot be bestowed upon their selection and management.

286. Heating-Surface.—The gases resulting from the combustion of coal on the grate have, on starting, a temperature of about 2400 degrees Fahrenheit, and should transfer as much of this heat as is possible, to the water contained in the boiler. To create a good draft in the chimney, a temperature of about 600 degrees above that of the outside air is required; 1800 degrees, or three-quarters of all the heat created, is therefore available. The boiler must be constructed with a view to absorbing all of these 1800 degrees.

The rapidity with which heat is transferred from one body to another is proportionate to the difference of temperature between them; the gases of combustion should therefore be conducted in such a course along the boiler that this difference will be at all points as large, and as uniformly the same, as possible—an object which will be best attained, if the gases are brought in contact with the coldest part just before escaping into the smoke-stack, and with the hottest part immediately after leaving the furnace.

The water being fed in at the lowest point of the boiler, it follows from the rule just given, that the gases should pass first along the upper hottest portions, descend gradually to the colder lower ones, and leave near the entrance of the feed-water.

That portion of the shell, which is covered with water inside and exposed to fire or hot gases outside, is the heating-surface. The capacity of a boiler for raising steam is directly proportionate to this heating-surface, the size of which, expressed in square feet, indicates—if the boiler is otherwise correctly constructed and supplied with a sufficient grate-surface—its value better than a certain number of horse-power.

The size of the heating-surface which is to represent one-horse power has not been established by the trade, and the seller is therefore at liberty to represent the boiler as powerful as his, sometimes elastic, conscience will admit.

Fifteen feet heating-surface at least should be allowed for one-horse power, although one-half of it may by forced firing be made to evaporate the same quantity of water.

In calculating the power of a boiler, it is to be considered, that the lower, nearly horizontal part of internal flues or tubes, owing to the difficulty with which bubbles of steam escape from under them, are found to be much less effective than the lateral and upper surfaces. To obtain therefore the real useful heating-surface, we have to deduct nearly one-third from the total one of the tubes or flues. On an average the effective heating-surface is from $\frac{3}{4}$ to $\frac{5}{6}$ of the total heating-surface.

It is always safer to buy a boiler of a fixed amount of heating-surface than of a number of undefined horse-power.

287. Combustion.—The useful parts of all fuel consist of the element carbon, which constitutes the solid parts, and of combinations of hydrogen and carbon in the forms of olefiant gas, pitch, tar, naphtha, &c. Both these elements, carbon and hydrogen, are, through the process of combustion, combined in gaseous form with the oxygen of the air, and escape as carbonic acid (CO_2) and water (HO).

If the disengaged carbon is chilled by a cold draft or otherwise below the temperature of ignition, before coming in contact with oxygen, it constitutes, while floating in the gas, *smoke*, and when deposited on solid bodies, *soot*. But, if the disengaged carbon is maintained at the temperature of ignition, and supplied with oxygen sufficient for its combustion, it burns, while floating in the inflammable gas, with a red, yellow, or white flame.

If the boiler, or more properly its heating-surface, is small, and the firing hurried in order to produce enough steam, the combustion must be imperfect, and a loss of fuel will be the consequence. A large heating-surface, may, compared with a small one, save in one year the cost of a boiler in fuel.

It has been found by experiments and calculation that it takes about 24 pounds of air, to furnish enough oxygen for the combustion of one pound of coal, and to dilute the gases properly.

It seems evident that such a large amount of air as 24 pounds, equal to 650 cubic feet, for one pound of fuel, cannot be introduced within the furnace without artificial means or draft.

288. Draft.—This draft is usually produced by a chimney, and sometimes by a fan or other blowing machine.

The gases inside of a chimney are expanded by heat, and therefore lighter than those outside, and the draft is proportionate to the difference in weight between the column of gases inside and that of an equal column or volume of air outside. The efficiency of a chimney depends therefore principally on the height of its crown above the fire-grate. Several formulæ have been proposed by which it is to be calculated, but local experience has usually the deciding voice.

It is, however, advisable to build the smoke-stack high enough, to answer not only present demands, but also increased ones which may be made in the future.

Small pieces of coal which have escaped through the chimney, can frequently be found in the screens, and sometimes in the paper, but if the stack is very high,

the smoke will be carried off to a distance, before its floating solid parts can reach the ground,—a great advantage, especially where soft or bituminous coal is used.

As a rule which will answer in most cases, a chimney may be built to a height of twenty-five times its inside diameter or width in the clear. The area of the width of a chimney can be made, 0.16, or $\frac{1}{6}$ the area of the fire-grate, if the latter is of the ordinary construction, or equal to the sum total of the area of the flues in any one place on the course of the hot gases.

The hot gases cool off, contract, and consequently require less room as they ascend through the chimney, and many scientific writers therefore recommend building the stacks conical or pyramidal inside and outside, that is, narrower towards the top than at the bottom.

It has, however, been lately found that smoke-stacks, constructed as inverted cones, or wider at the top than the bottom, give a better draft. This contradiction of the long-followed theory is in practical use on most locomotives and in the brick chimneys of numerous factories, and it may be stated, that such stacks are much lower than anybody would dare to build them on the contraction plan, and that they generally give satisfaction.

They are perfectly perpendicular outside, and are made funnel-shaped inside by means of a double wall. The outside wall may, for instance, start at the bottom with a full brick of 9 inches, and run out at the crown with one-half brick, or $4\frac{1}{2}$ inches, while the inside wall is only half a brick, or $4\frac{1}{2}$ inches, thick, parallel with the outside one, connected with it at intervals by a brick or *binder*, but leaving a few inches distance between the two. This inside lining is only carried up for a part of the height, and then broken off, thus leaving the top considerably wider than the lower part.

The foundation of a chimney should be as solid as a rock, as it has to sustain the enormous weight of the bricks which are piled upon it. The slightest sinking of a part of the foundation may cause the top to lean over and perhaps to fall.

Access must be provided to the inside of the stack, through an iron door or through an arch near the bottom, for the removal of the ashes which will gather there in the course of time.

The hot gases always carry some fine dust or coal along, and deposit them on parts of the boiler over which they pass; the portion of the heating-surface thus covered, is ineffective, and it is therefore imperative that the flues and boiler-surfaces should be frequently cleaned, and doors must be provided for that purpose.

289. Grate-Surface and Firing.—The ordinary rate of combustion for factory boilers is, according to Rankine, from 12 to 16 pounds of coal per hour on every square foot of grate-surface, the size of which may be approximately determined from this. The same writer not only recommends a sufficiently large grate-surface, but warns us against any increase of its size beyond the prescribed limits, because too much air would then be admitted, and absorb a great deal of the heat without being of any use.

The admission of air can, however, be well regulated by the damper, and we

cannot conceive why a large grate-surface, which permits slow combustion with little draft and a light covering of fuel, should be objectionable.

We have lately seen a system of boilers which confirms this opinion. They are twin boilers, consisting of a lower cylinder, fitted with 2- or 3-inch flues, and an upper plain cylinder. They are not walled-in in the ordinary manner; the lower cylinder, resting with its ends only in the two short walls, hangs free, so that the fire can play all around it. The upper cylinder rests above the lower one in the same two end walls, and the long side walls are arched up, so that they join it all along on both sides. This brings the upper half, or its steam-room, beyond the reach of the flames, while the lower half is open to the fire, like the lower flue-cylinder, from which it is not separated by any arches or partitions. The grate occupies the whole space between the four walls under the boiler, and is three or four times as large as usual. The fire-doors are on the long side of the boiler and as numerous as the room permits. When two such boilers are required, they are walled in between the same four walls and above one common grate without any separating walls. The grate being very wide, it is then necessary to have fire-doors on both long sides. The fire or hot gases, after having passed around the lower cylinder and below the upper one, are conducted to the outside at the end, which in ordinary boilers contains the fire-doors, and descend from there through iron conduits into the flues of the lower cylinder, through which they pass to the stack. The grate should be at a convenient height above the ground for the work of the fireman, and as the lowest part of the boiler must be at some distance above the fuel, the whole structure becomes necessarily very high. The large grate-surface is slightly covered with coal, which is thrown in through each door in regular succession, and thus kept uniformly spread. Very little draft is required, and the combustion seems to be perfect. These boilers are in operation at the paper-mills of Mr. George B. Connard, Reading, Pa., and at the works of the American Wood-Paper Company, at Royer's Ford, Pa., and we have been informed that they furnish in one case, with 7 tons of coal, as much steam as others, which had been previously used, would produce with 10 tons; and that in the other the consumption of coal had been reduced by their introduction from 20 to 9 tons for exactly the same work.

If a boiler is provided with only a small grate-surface, the necessary amount of combustion of fuel cannot take place without a strong draft, or in other words, the air must be forced through the coal and along the boiler with great rapidity, sometimes so fast that it can neither become well heated nor thoroughly deprived of its oxygen. The necessity for a strong draft indicates, therefore, that the grate-surface is not sufficient; and it would probably result in a great saving of fuel for many boilers if their fire-places were extended and their drafts reduced.

Smoke is not only a nuisance, but also a loss of as much unburnt coal; it escapes in thick clouds when the fire-doors are opened and fresh, especially finely divided, coal is thrown in. The cold air reduces the temperature while the draft carries off small particles of coal untouched.

A simple way to prevent this loss, to some extent, which is applicable to any common steam-boiler, consists in the division of the grate into two separate parts by a brick wall in the middle parallel with the grate-bars. Each division has a separate door, and while the heat is greatest in one of them, fresh coal is thrown into the other; the unconsumed coal which is carried off by the draft, mingles with the flames from the hot division, and is thus burnt up. The sudden changes of temperature, which are so injurious to the boilers, caused by the opening of the fire-door, are thereby also in a measure prevented.

A constant stream of fresh air is often conducted into the fire-hearth through channels in the brickwork, wherein the air on its passage is partly heated.

Ordinary grates are composed of straight, narrow cast-iron bars, laid alongside of one another, and leaving for a coal-fire, openings enough between them to amount altogether to one-fourth of the area of the grate-surface. (Redtenbacher, *Resultate für den Maschinenbau.*)

These bars, when heated, expand, and become frequently warped into such crooked forms, that they have to be replaced by new ones. Many patent grate-bars have been constructed with a view to prevent any change of their outer form, or of the open space for the admittance of air, by providing room for expansion and contraction in the bars themselves. Some of them are quite successful, and not only save coal, but also last much longer than the common bars.

It is a mistake to suppose that the sprinkling of water over coal will improve combustion; the water must be evaporated and transformed into steam, absorbing thus a great deal of heat at the expense of the fuel.

The coal must be spread on the grates uniformly, and not too thickly, and if stirred at all, it is to be done from below.

A good fireman can economize more than all the inventions which have been made for this purpose are able to do, while a careless or ignorant one may waste many times the amount of his wages in fuel.

Several years ago prizes were offered to such firemen, as should prove themselves most efficient at a competitive trial, at Mühlhausen, then in France, now belonging to Germany. Forty-four offered themselves, and the best eighteen were selected from the number; each one fired up during ten hours with the same boiler, fuel, &c., and it was found that the best fireman could evaporate nearly twice as much water with the same amount of coal under exactly the same circumstances as the worst one. To appreciate this result, it must be considered that only experienced men offered themselves for the trial, and that only one-half of these were admitted.

290. Construction of Steam-Boilers and Test.—The designs for the construction of steam-boilers are so numerous that a description cannot be attempted in this book, but we shall say a few words which apply to them all.

It has been found by experience that a thickness of $\frac{3}{8}$ inch is the most favorable to sound riveting and caulking of boiler-plates, and they are therefore seldom used much thicker or thinner.

If a cylindrical boiler is required to endure an unusually high pressure, the necessary increase of strength must be attained, not by increased thickness of the plates, but by diminution of the diameter (see article 11, page 30).

The flat ends of cylindrical boilers are given about once and a half the thickness of the cylindrical portions; cast-iron should not be used for them nor for any other part of the shell. These flat ends are usually connected with each other by longitudinal stays, and sometimes with the cylinder by means of angle iron, but such rings are liable to split at the angles, and it is therefore preferable to bend the edges of the flat ends and rivet them to the cylinders.

Plates which overlap one another should have the overlapping joints facing upwards, on the side next to the water, that they may not intercept bubbles of steam on their way upwards. The joints in horizontal flues should be placed so that they do not oppose the current of the gases. Those parts of boilers which are exposed to more severe or more irregular strains than the rest, or to a more intense heat, should be made of the finest iron.

Lately there have been some steam-boilers built of steel plates. As they have about one-half more tenacity than iron ones, they can be made lighter, and it is not unlikely that steel boilers will take the place of iron ones at some future day.

In paper-mills the demands for steam are often so sudden and large, that some of the water will be carried along mechanically through the violence of the motion, unless a large store-room for both water and steam, but especially for the latter, is provided. A steady pressure is particularly required for the paper-machine, and large boilers, with plenty of steam-room, will be more apt to furnish it than small ones.

Every boiler, before being put into operation or walled in, should be tested with a hydraulic pressure twice as great as the highest steam-pressure allowed to it. Water-pressure is used on account of the absence of danger, in case any part of the boiler should give way.

291. Feed-Water.—If possible, the boilers should be fed with hot water; not only because as much heat as it contains is directly saved, but also for the reason that the injection of cold water chills and may injure the hot plates. There are plenty of sources in a paper-mill from which hot water may be obtained, but the dryers of the paper-machine are the principal ones. The condensed steam is conducted through a pipe into a reservoir or tub, and if too hot to be pumped, it is therein mixed with fresh water and forced into the boiler by the feed-pump. These pumps refuse to work with highly heated or boiling water, and large quantities of escaped steam from steam-engines, by which the temperature of the feed-water might be raised to the boiling-point, are often allowed to blow out into the open air, because they would heat the water too much.

Such steam can, however, be utilized by being conducted through long coils of pipe, fastened in an upright steam-tight cylinder of boiler iron, interposed between the pump and the boiler. The feed-pump forces the hot water first into this cylinder or

heater, where it acquires a very high temperature in contact with the steam coil, and thence through the usual check-valve into the boiler. The feed-water does not pass through any pump after it has left the heater, and can, therefore, be raised to any temperature.

It is of the greatest importance that the water in the boiler should be kept at the right height all the time, and since the regular feed-pump may get out of order, there should be a second one, or some other means, provided, by which the supply can be kept up in such a case. Giffard's injector, or steam-pumps, may be recommended for this purpose, on account of their independence of any gearings or motors, but as all of them consume steam, and some will not feed with hot water, the regular feed-pump is always to be used in preference.

A valve must be provided at the lowest point of every boiler, through which it can be emptied; this valve or blow-off cock must be frequently opened to enable the deposits of salts or mineral matters to escape before they have had time to solidify. According to the quality of the feed-water this has to be done several times, or only once a day, and the boilers should in all cases be emptied entirely at regular intervals.

Some substances occurring in feed-water seem to stick so closely to iron that they cannot be removed by blowing off water; they must be chemically dissolved, and numerous powders and liquids are sold at high prices for this purpose, but the introduction of one or more gallons of common coal oil or petroleum will answer in many cases just as well or better.

292. Explosions.—We quote here from remarks made on this subject by W. T. Macquorn Rankine, Professor of Engineering and Mechanics in the University of Glasgow, in his *Manual of the Steam-Engine and other Prime Movers*—a work which has furnished much data for this chapter:

"Explosions result:

"I. *From original weakness.* This cause is to be obviated by due attention to the laws of the strength of materials in the designing and construction of the boiler, and by testing it properly before it is subjected to steam-pressure.

"II. *From weakness produced by gradual corrosion of the material of which the boiler is made.* This is to be obviated by frequent and careful inspection of the boiler, and especially of the parts exposed to the direct action of the fire.

"III. *From wilful or accidental obstruction or overloading of the safety-valve.* This is to be obviated by so constructing safety-valves as to be incapable of accidental obstruction, and by placing at least one safety-valve on each boiler beyond the control of the fireman.

"IV. *From the sudden production of steam of a pressure greater than the boiler can bear, in a quantity greater than the safety-valve can discharge.* There is much difference of opinion as to some points of detail in the manner in which this phenomenon is produced, but there can be no doubt that its primary causes are, first, the overheating of a portion of the plates of the boiler (being in most cases that portion called the 'crown of the furnace,' which is directly over the fire), so that a store of heat is accumulated, and secondly, the sudden contact of much overheated plates with water, so that the heat stored is suddenly expended in the production of a large quantity of steam at a high pressure.

"Some engineers hold that no portion of the plates can thus become overheated, unless the level of the surface of the water sinks so low as to leave that portion of the plates above it uncovered; others

maintain, with Mr. Boutigny, that when a metallic surface is heated above a certain elevated temperature, water is prevented from actually touching it, either by a direct repulsion or by a film or layer of very dense vapor, and that, when this has once taken place, the plate, being left dry, may go on accumulating heat and rising in temperature for an indefinite time, until some agitation or the introduction of cold water shall produce contact between the water and the plate and bring about an explosion. All authorities, however, are agreed that explosions of this class are to be prevented by the following means:

> "1. By avoiding the forcing of the fires, which makes the boiler produce steam faster than the rate suited to its size and surface.
>
> "2. By the regular, constant, and sufficient supply of feed-water, whether regulated by a self-acting apparatus or the attention of the engineman to the water-gauge. And
>
> "3. Should the plates have become actually overheated, by abstaining from the sudden introduction of feed-water (which would inevitably produce an explosion) and by drawing or extinguishing the fires, and blowing off both the steam and the water from the boiler."

Steam-boilers have been in the German States for many years under the control of the governments, and the vast experience gathered during that time has been used to frame a new law for their construction, which has lately gone in operation in the Empire.

As the sole object of the law is to prevent explosions, it may be interesting to citizens of other countries to learn its provisions. They deserve to be recommended everywhere.

The following extract, translated by the author, contains all the provisions concerning such stationary boilers as are used in paper-mills:

I. *Construction of Steam-Boilers.*

"Sec. 1. No parts of a steam-boiler, which come in contact with the fire or hot gases, shall be made of cast iron, if their inside diameter is over 10 inches for cylindrical and over 12 inches for spherical forms.

"Sec. 2. The highest part of all fire-flues, passing inside or outside of the boiler, must be at least 4 inches below the fixed point, beneath which the surface of the water is not allowed to fall.

"This regulation, however, applies not to boilers composed of tubes of less than 4 inches diameter, nor to flues in which there is no danger, that the iron in contact with the steam-room may become red-hot. The danger of overheating may be considered excluded if the fire passes a heating-surface, covered with water, of twenty times the area of the grates for natural draft, and forty times for artificial draft, before it can reach that portion of the shell which is in contact with steam.

II. *Steam-Boiler Fixtures.*

"Sec. 3. Every steam-boiler must be provided with a feed-valve, which is closed by the pressure inside of the boiler as soon as the feeding apparatus stops to force water in.

"Sec. 4. Every steam-boiler must be provided with two reliable feed arrangements, not depending on one or the same shaft or motor, and each one of which separately is capable to supply the boiler with all the water required. Several permanently connected boilers are for this purpose to be considered as one.

"Sec. 5. Every steam-boiler must be provided with a water-glass and with a second arrangement, by means of which the height of water inside can be known. Each one of these fixtures must have a

separate connection with the interior of the boiler, unless the connection common to both is made by means of a pipe, not less than 3 inches inside diameter.

"Sec. 6. If gauge-cocks are to be used, the lowest one of them is to be placed on a level with the fixed point, below which the water is not allowed to fall. All these cocks must be constructed so that they can be freed from incrustations by pushing through them in a straight line.

"Sec. 7. The point below which the surface of the water is not allowed to fall, is to be marked on the water-glass and on the iron, or mason work of the boiler, in a distinct and striking manner.

"Sec. 8. Every steam-boiler must be provided with at least one reliable safety-valve. Two safety-valves are sufficient for several boilers, if they have one steam-room in common, from which they cannot separately be closed out. Steamboat, locomobil, and locomotive boilers must always have at least two safety-valves.

"Sec. 9. Every steam-boiler must be provided with a reliable pressure-gauge, on which the highest allowance of steam pressure is to be marked in a distinct and striking way.

"Sec. 10. The highest steam pressure allowed, the name of the maker, and the year when it was built, must be marked on every steam-boiler in a permanent and distinctly visible manner.

III. *Testing of Steam-Boilers.*

"Sec. 11. Every steam-boiler before being set up, walled in, or covered over, must be tested with water pressure, while all its openings are well closed. Boilers which are limited to five atmospheres overpressure (75 pounds) or less, are to be tested with twice the highest pressure which they are allowed to carry. Boilers, intended for higher pressures, require a test with five atmospheres added to the allowed pressure. The pressure of one atmosphere is understood to be that of one kilogramme on one square centimeter (15 pounds English on one square inch). The sides of the boiler must stand the test without showing any permanent change of form or leakage. They are considered leaky (not tight) if the water at its highest pressure escapes through the joints in other forms than that of mist or fine drops.

"Sec. 12. If boilers have been repaired at the shop, or laid bare at the mill, for this purpose, they have to be subjected to the same tests as new ones. If the inner flue of a boiler, or the fire-box of a locomotive boiler, has to be taken out for repairs or removal, or if one or more plates of a cylinder-boiler have to be renewed, the boilers must be tested before being again used, though it may not be necessary to lay the whole boiler bare.

"Sec. 13. The pressure, used at the test, is to be measured with a sufficiently high, open mercury gauge, or with the gauge carried by the examining official. There must be some fixture on every steam-boiler, which enables the examining official to attach a pressure gauge.

IV. *Erection of Steam-Boilers.*

"Sec. 14. Steam-boilers, which are intended for more than four atmospheres overpressure, and those, in which the sum obtained, by multiplying the number of square meters (11 square feet English) of heating-surface with the number of atmospheres in the steam pressure, is over twenty, are not permitted to be located under rooms which are frequented by men. They cannot be admitted into such buildings if there is an arched or timber ceiling above the boilers. Every boiler situated under rooms frequented by men must be provided with arrangements by means of which the influence of the fire on the boiler can be immediately stopped.

"Steam-boilers composed of tubes of less than 4 inches inside diameter, are exempt from these regulations.

"Sec. 15. A space of 3 inches must be left between the outside of the brickwork, inclosing the boiler, and the surrounding walls of the building. This open space may, however, be covered on top and at the sides."

293. Safety-Boilers.—A large number of steam-boilers have within late years been constructed in a manner which makes destructive explosions impossible.

The strongest boilers are those which are entirely composed of tubes, and small cylinders or spheres. They are not only the strongest but also the safest, because a cylinder of very small diameter cannot hold water or steam enough to do any serious damage if exploding.

One of the most prominent safety-boilers is composed of any desired number of cast-iron balls, the several open-curved necks of which are turned so as to fit into one another; iron bolts passing through a number of them, hold them tight together in the joints. The balls are of 8 inches external diameter, $\frac{3}{8}$ inches thick, and several of them cast in one piece, or one alone, may form an element. Strings of balls thus composed and connected are laid in an inclined position across the furnace and grate; the fire passes around them and goes to the chimney through a flue below.

Whenever the pressure inside of this boiler is too high, the balls expand where the spherical form is preserved, and contract in the line of the openings or necks, the joints thus open like as many safety-valves, and the steam escapes without doing any harm. If a ball breaks or bursts, the destruction is confined to it alone.

These boilers are perfectly safe, but they have some disadvantages. The spherical elements, being in an inclined position, do not discharge all their contents when the boiler is emptied; a portion remains in the lowest parts, which form bags or cavities.

Sediment and incrustation soon fill up these cavities, and reduce the heating-surface by as much as they cover.

Though the inventor and maker has succeeded in casting the balls in a very superior manner, breaks will yet occur, and necessitate the stoppage of the boiler and replacement of the broken ball by a new one.

Numerous other inventors have made combinations of wrought-iron tubes or pipes, which are preferable to castings, because they are less apt to break, and because their thinner shells admit of a quicker transmission of heat from the gases to the water. The pipes are connected in almost every conceivable form, and sometimes also compose the fire-grate in the place of bars.

The capacity for water and steam in all these boilers is necessarily very limited, and no large amount of either can be stored up. To obviate this difficulty, steam-drums are added on top and water-drums below. If these reservoirs are not in contact with fire, they will not contribute to the economy of fuel, but they may be used with perfect safety, provided they be strong enough to endure the highest pressure which will ever be raised in the boiler.

In paper-mills large quantities of steam are often suddenly drawn from the boilers, while at other times very little is required.

The use of small tubes or balls, on which safety-boilers are based, excludes the possibility of providing steam and water-room of a capacity proportionate to the large heating-surface, and unfortunately compels the proprietors of paper-mills to adopt other systems.

To overcome this difficulty several inventors have constructed boilers, which are combinations of cylinder-boilers with systems of wrought-iron tubes. But whatever device may be used, and however excellent it may be in other respects, a steam generator cannot be considered a safety-boiler, if fire or hot gases are allowed to come in contact with a cylinder of more than 4 inches diameter, which contains water and forms a part of the boiler.

294. Consumption of Fuel.—In the best regulated paper-mills, where all the power is furnished by water, and rags or old papers constitute the raw material, from $\frac{3}{4}$ to 1 pound of good Pennsylvania coal is used for every pound of paper made.

SECTION IV.

Steam-Engines.

295. Expansion.—The steam-engine has been much improved since its invention about one hundred years ago, but the fundamental principles governing its construction, are yet the same as laid down by Watt.

The power of the steam-engine is derived from the alternate action of the steam upon the two sides of a piston, which is thus moved from one end of a cylinder to the other, the reciprocating motion being changed into a rotary one by means of a crank.

We suppose the piston of a high-pressure engine, for an example, to have arrived at one end of its course, and to be on the point of starting to return, forced by steam admitted into the narrow space behind it, while the empty cylinder in front communicates with the open air. If the steam is of 60 pounds, equal to 4 atmospheres over-pressure, its real pressure will be 75 pounds, or 5 atmospheres, which, being opposed by one atmosphere, or 15 pounds only on the other side, pushes the piston forward with 60 pounds to every square inch of its surface.

If fresh steam is admitted constantly during the whole course of the piston, the largest amount of power of which the cylinder is capable, will be produced, but the steam leaves the engine with nearly its full pressure.

If we take, for a second example, a cylinder of the same diameter, but of twice its length, and admit only the same amount of steam for each stroke, as in the first example, we find that, after the fresh steam has been shut off, the piston is yet moved forward to the other end by the steam, which filled one-half of the cylinder.

This second half of the movement of the piston is produced by expansion, and through it, if extended far enough, can the pressure of the steam be utilized and reduced until it is nearly equal to that of the atmosphere, or 15 pounds.

It is evident that all the power, produced by expansion in the second example, with the same quantity of steam as was used for the first example, is clear gain as compared with the latter, and though this is not exactly so in practice, it yet explains the economy of expansion. These examples show also, that a larger cylinder is capable of producing the same power with less steam than a small one, or that engines of ample capacity are the most economical, if provided with proper arrangements for expansion.

296. Condensation.—Another way of increasing the power of an engine is, to reduce the counter-pressure by the creation of a vacuum.

The steam, instead of escaping into the air, is for this purpose conducted into an apparatus, where it is suddenly condensed by contact with cold water finely divided by a sprinkler. The water used for this condensation is thereby highly heated, the counter-pressure reduced considerably below 15 pounds, and the power exercised on the piston increased as much.

The use of these condensers thus enables an engine to work with very low steam-pressure, and reduces the danger to which high pressure in the boilers exposes it.

297. Different Systems of Engines, and Utilization of Escaping Steam.—All engines may be divided into—

I. Non-condensing or high-pressure engines;

II. Condensing engines.

High-pressure engines are simple in construction, easily managed, and therefore generally used whenever steam is only an auxiliary power, to be stopped and started according to the state of the water-power. The valve which admits the steam is usually regulated by a governor, which is set in motion by the line-shaft. If the shaft turns too fast or too slow, the governor closes or opens the valve, letting in less or more steam and increasing or decreasing the expansion.

The escaping steam should never be allowed to waste directly into the air; it can be made useful by passing through a coil or other system of pipes immersed in water, or it may be conducted through large pipes and heat the building, or into the mixing-pans to boil the liquors.

In some mills, which run by steam-power altogether, the escaping steam is thoroughly used up for boiling waste-paper in tubs, and by heating the mill and the feed-water for the boilers. One mill, which from waste-paper and with steam-power only, produces 5000 pounds of good printing-paper per day, economizes so well that direct steam is not used anywhere except in the steam-engines. It has been stated to us that the establishment consumes only 1500 pounds of coal per day over and above the amount, which would be required if the power were furnished by water.

The dryers form a natural condenser for the high-pressure engines which are used for driving paper-machines.

Condensing engines require large quantities of water, are complicated and expensive, but they furnish more power with the same amount of fuel than any other kind. This is especially the case when high-pressure steam first acts in a small cylinder,

from which it passes into a larger one, where it propels the piston by expansion and condensation.

The escaping steam can, however, be so well utilized in many paper-mills that the simpler high-pressure engines answer often as well as more complicated ones.

It is indifferent whether an upright or horizontal engine is selected, provided it be a good one, fastened on a solid foundation.

298. Power of Engines.—The statement that a steam-engine gives a certain amount of horse-power must be made in connection with that of the dimensions of the cylinder, steam-pressure, speed, expansion, &c., if it is to be of any value. A steam-engine will give nearly double power if its speed is doubled. Fast-running engines not only wear out soon, but get more easily heated and out of order; and while it is the seller's interest to speed them high and represent them more powerful, the purchaser's is just the reverse. Steam-engines should therefore be purchased according to their size, but not by the horse-power.

The power of an engine is the total mean pressure on the surface of the piston, less the pressure against it in pounds, multiplied with the velocity of the piston in feet per minute. This product must be divided by 33,000 if the theoretical horse-power is to be obtained; and from it we have to deduct for condensing engines 25 per cent. and for high-pressure engines 13.1 per cent. loss from friction and pumps, in order to find the actual horse-power. While the steam is expanding in the cylinder, its pressure decreases constantly, and to make an exact calculation we have to determine its mean pressure.

The following table gives the mean pressure for steam of from 40 to 100 pounds and grades of expansion from $\frac{1}{4}$ to $\frac{7}{8}$. An expansion of $\frac{1}{4}$, for instance, means that fresh steam is admitted into the cylinder for $\frac{3}{4}$ of a stroke or of the length of the cylinder, while only during the last quarter the piston is moved by the expanding steam:

Pressure in Pounds.	Grade of Expansion.							
	$\frac{1}{4}$	$\frac{1}{3}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{2}{3}$	$\frac{3}{4}$	$\frac{7}{8}$
40	38.550	37.333	36.750	33.860	29.670	27.964	23.860	15.395
45	43.368	42.000	41.341	38.092	33.378	31.459	26.842	17.319
50	48.187	46.666	45.937	42.325	37.067	34.955	29.825	19.243
55	53.005	51.333	50.530	46.557	40.775	38.450	32.807	21.167
60	57.822	55.999	55.122	50.790	44.520	41.946	35.790	23.090
65	62.640	60.666	59.715	55.022	48.228	45.441	38.772	24.924
70	67.460	65.333	64.300	59.255	52.419	48.937	41.755	26.694
75	72.278	69.999	68.893	63.487	56.127	52.432	44.737	28.626
80	77.096	75.666	73.500	67.720	59.340	55.928	47.720	30.790
85	81.914	80.333	78.093	71.952	63.048	59.423	50.702	32.714
90	86.730	83.999	82.680	76.180	66.750	62.919	53.680	34.638
95	91.548	88.666	87.273	80.412	70.458	66.414	56.662	36.554
100	96.370	93.333	91.870	84.650	74.170	69.910	59.650	38.480

If we have, for example, a high-pressure engine of 15 inches diameter of piston, 3 feet stroke, 60 pounds of steam, 50 revolutions per minute, and an expansion of $\frac{1}{2}$, the steam acts on a piston surface of—

$$\frac{15 \times 15 \times 3.14}{4} = 176.6 \text{ square inches,}$$

and the mean pressure on the piston for a steam-pressure of 60 pounds above the atmosphere, or for $60 + 15 = 75$ pounds, is, according to our table, 63.487 pounds. The atmospheric counter-pressure, which is equal to 15 pounds to the square inch, must be deducted from these 63.487, and leaves 48.487 pounds as the available pressure. The theoretical power is therefore:

$$\frac{\underset{\text{Square inches piston surface.}}{176.6} \times \underset{\text{Pressure per square inch.}}{48.5} \times \underset{\text{Feet stroke.}}{3} \times \underset{\text{Revolutions per minute.}}{50} \times \underset{\text{Strokes during one revolution.}}{2}}{\underset{\text{One horse-power.}}{33{,}000}} = 77.85 \text{ horse-power,}$$

and deducting from the theoretical power

13.1 per cent., = 10.20 loss,

we obtain

the actual horse-power = 67.65

299. Losses of Power.—We have supposed the pressure to be 60 pounds, as indicated by the gauge; but if this is the pressure in the boilers, the steam will have lost a considerable portion before it reaches the engine; even if the conducting-pipes are short and well covered, the difference may amount to many pounds.

The cylinders are usually not so well covered as they should be, and lose pressure by the radiation of heat.

Water takes up frequently a part of the room which should be occupied by steam; and if the piston does not fit to a nicety, fresh steam escapes between it and the cylinder.

The counter-pressure is always higher than that of the atmosphere, or 15 pounds, as we have supposed it to be, the friction of the steam in the waste-pipes consumes power, and allowance must be made for the loss of fresh steam, which fills the channels and the space between the piston and the heads of the cylinder.

If the escaping steam is utilized, as it ought to be, by passing through pipes, surrounded by air or water or other liquids, or by direct introduction into the latter, the counter-pressure will be thereby considerably increased.

The total amount of loss from these sources is very different, according to the construction, disposition, and management of the steam-power; it can hardly be calculated, but can only be found by experience; a sufficient allowance should be made for it, so that the engine need not be forced.

The pipe which conducts fresh steam to the engine should not have less inside diameter than one-quarter of the diameter of the piston, and the escape or waste-pipe is to be as large as possible, but not less than one and a half times as large as the steam-pipe which connects with the boilers.

The cylinder is to be provided with small pipes fastened to the lowest points of the heads, through which the condensed water can be blown off outside of the room.

300. Disposition and Management.—Steam-engines of very regular speed are required in paper-mills, and especially for the paper-machines; they should be well built, and provided with sufficiently large fly-wheels and good governors.

They must be mounted on solid frames in such a manner that none of their parts can deviate in the slightest degree from their relative situations. Too much attention cannot be given to this point as well as to solid, heavy foundations.

The connection between the steam-engine and shafting is now generally made by means of belts, either from separate pulleys or directly from the fly-wheel.

If the steam-power is only used to supply the deficiencies of a water-power, steam-engine and water-wheel may both drive the same shaft. The water-wheel gate must be opened sufficiently to admit all the water furnished by the stream; while the engine, which drives the same line shaft with a belt, is regulated by the governor, so as to furnish the balance of the required power, whatever it may be.

No greater mistake can be made than to give charge of a steam-engine to a cheap but incompetent man. Not only will the engine itself be ruined, but it will not furnish as much power from a certain quantity of steam as it should, and consume in wasted fuel many times the wages of a good engineer.

The best available man should be selected for this purpose, one who is desirous of instructing himself, and who takes pride in the good performance and clean condition of his engine.

SECTION V.

PIPES.

301. Their Use and Disposition.—Steam as well as water loses power by friction, by a change of direction in corners and angles, and by contraction. All pipes for their conveyance should therefore be as short, straight, and wide as possible; by every superfluous piece of pipe or elbow a quantity of pressure, requiring a certain number of pounds of coal for its production, is lost. A saving of first cost may be accomplished by the use of narrow pipes in the place of large ones, but it is done at the expense of a permanent loss of pressure or fuel.

Cast-iron pipes are cheaper and more durable for large sizes, but wrought-iron ones are preferable for narrower ones, because they can be more easily put together;

pipes of inside diameters of 2 inches or less may be of wrought-iron, but all those of larger sizes should be of cast-iron.

Every piece of pipe should have been tested with high pressure before it is used.

A set of taps and dies to cut threads on pipes of 2 inches diameter or less, and some of the most used valves, fixtures, and pipes, should be kept on hand at the mill, so that any leaks or breaks can be quickly repaired.

Steam loses heat during its passage through pipes, unless they are well surrounded by non-conducting materials. It is advisable to wrap good, tough paper—one of the best non-conductors—around the pipes, and tie or sew old felting, or some other cloth, around them. Too much care cannot be given to this seemingly unimportant point; its neglect has cost many tons of coal which might otherwise have been saved.

Steam pipes should, wherever it is feasible, be disposed, so that the water resulting from condensation cannot gather anywhere, and will flow back into the steam-boiler.

If this cannot be done, the water should be drawn off into self-acting *steam-traps* at the lowest points. Some of these traps consist of iron boxes, wherein the water is collected, until it rises high enough to open an outlet-valve by means of a swimmer or float; but they are considered not so reliable as those which are based on the contraction and expansion of metals.

In those of the latter construction the steam-pipes are likewise connected with a small iron box or reservoir, from which a long iron or brass pipe extends to a distance of about 10 to 15 feet, fastened at the far end, and attached with its loose end in the box to an outlet-valve. While the pipe is filled with steam and expanded to its greatest length, the valve remains closed; but the pipe contracts as soon as its temperature is reduced by the substitution of condensed steam for live steam, it then opens the valve, and discharges the water. The operation of this steam-trap is based upon the fact that steam of any pressure above the atmosphere, has always a higher temperature than water, which cannot rise above the boiling-point, or 212 degrees Fahr.

The water which escapes from these steam-traps, should be collected in a reservoir and fed to the boilers.

Many different kinds of paint are used to preserve iron, and especially pipes, against rusting, but according to the author's experience, none answers so well as red lead. All iron pipes should be covered outside and inside, as far as possible, with red lead paint.

It is a condition upon which depends the economical arrangement of a mill that the steam-generators should be near the parts which they have to supply, such as steam-engines, paper-machine, rag-boilers, so that only few steam-pipes shall be required.

SECTION VI.

Pulleys, Belts, and Gearings Generally.

302. Belts.—The transmission of power or motion to the different parts of a mill is at present accomplished principally by shafts, pulleys, and belts, cog-wheels being used only where they cannot well be avoided. Pulleys and belts are preferred because their shafts can be placed at nearly any distance from each other, because they are subjected to no breaks which cannot be quickly mended, and because they work without noise.

The friction on the pulleys, which alone enables a belt to transmit power from one pulley to the other, is directly proportionate to the surface covered by the belt. Everything else being equal, belts cover a larger part of both pulleys the further they are apart.

The friction is also dependent on the tension of the belt or the tightness with which it fits on the pulleys. A long belt is pressed to the surface of the pulleys by its weight, but a short one must be stretched more, in order to lay equally as tight, and it will consequently wear out sooner; long belts are therefore more durable and work better than short ones.

If the power, which is to be transmitted during a given time, is distributed upon a large number of revolutions, the belt will not be strained much at any one time; but its tension becomes very great if the motion is slow. Fast-running pulleys require, therefore, smaller belts than slow ones, and are preferable.

The ends of a belt may be fastened together with hooks or lace-leather, and great care must be taken to cut them perfectly square, so that the length remains the same all across.

The laces should not be crossed on the inside, and must be evenly divided.

The more nearly an equal thickness and perfect straightness are secured in the belt throughout its whole length, the better will it perform its work.

Rubber belts, composed of alternating layers of rubber and cotton-cloth, have taken nearly altogether the place of leather ones, because they are not so sensitive to moisture and give more friction; but in perfectly dry places their relative prices should alone decide which kind is to be used.

303. Pulleys.—If oil, or even water, is allowed to get on the belt or pulley, it may reduce the friction so that the belt will slip and refuse to work. While this is the case, the belt is rubbing constantly against the pulley, and is thereby worn out more in hours than in weeks of regular work. If the pulleys are in an atmosphere of steam, the latter will soon condense on the cold surfaces, and in winter this is sometimes a

source of so much trouble, that it becomes necessary to keep the steam suspended as vapor by heating the room.

Pulleys are frequently covered with leather or rubber to increase the friction, but, if they are only true and well balanced, this is hardly necessary, although it may be useful. It is astonishing to see how many pulleys do not run true, because they are either badly cast and balanced, or not bored out correctly; such pulleys are very injurious to the belts. No first-class machine-shop will permit a pulley to be shipped with a heavy side and without having been thoroughly examined.

If the pulley has in some place a larger diameter than in others, the tension, and with it the friction of the belt, must be larger there than anywhere else; the belt will therefore constantly shift over to it. This explains why—in order to keep the belt in the middle—it is only necessary to turn the pulley a little full in the middle, so that the surface presents a curved instead of a straight line.

The pulleys must be fitted to the shaft with great care; if they are bored out too large, they can hardly be put on so as to run true. The entire lengths of all shafts, carrying pulleys or wheels, should be turned.

It is more convenient to the makers to fasten the pulleys on the shafts with set-screws, but they become a source of trouble at the mill. The point of the set-screw alone connects the pulley with the shaft and transfers the power from one to the other; it breaks off frequently or carves out a channel in the shaft, thus injuring it irredeemably. Pulleys which have any considerable amount of work to do, should always be fastened with keys.

304. Cog-Wheels and Shafts.—It is theoretically possible to construct a pair of gear-wheels so that the cogs of the driving one will only push, or roll upon, those of the driven one without perceptible friction. It is stated, that wrought-iron wheels have been cut out with such perfection, that no sound betrayed their motion.

Manufacturers generally can, however, not afford to use wheels of that kind; they must content themselves with cast-iron ones; but the greater or lesser noise which they produce in running, indicates the degree of skill with which they have been constructed.

If very large cog-wheels are required, it is better to give wooden cogs to one of them (to the driving one), as they will cause less loss of power from friction and less noise than iron running on iron.

Such cogs should be made of tough, close-grained wood, and cut out a long time before they may be needed, so that they will be well seasoned when they are to be fitted on the wheel.

Cast-iron shafts may, and ought to be, at present considered a thing of the past, as there is in most cases not even economy in their use; they must be made so much heavier than hammered ones, that the difference in the price per pound is nearly made up by the increased weight, while at the same time cast iron, being of a more brittle nature, breaks more easily, and is generally less reliable.

305. Bearings.—The rays of the sun are the source of all heat, and consequently

of all power; they raise by evaporation the water, which has passed through our streams, gather it into clouds and deposit it on the mountains and highlands, whence it descends again, forming waterfalls and driving our wheels; and the heat furnished by these rays is found stored up in the bowels of the earth as decayed vegetable matter or coal.

The power which is derived from these reservoirs of heat cannot be *annihilated*, and although we call it *wasted* whenever it is *misapplied*, its presence must manifest itself by some action.

A portion of the available power of a mill is always absorbed by the friction of the shafts in their bearings, and sometimes to such an extent that it reproduces heat; but ordinarily it is consumed by the combustion of lubricating-oil or by wearing off—perhaps so gradually as to be hardly perceptible—the metal of shafts and bearings, but especially of the latter, which is usually the softer one of the two. The oils and fatty matters which we interpose between the metal surfaces not only reduce the friction, but also serve as scapegoat for the shafts and bearings, by absorbing the power or heat through slow combustion.

If the weight of a shaft is divided on a large supporting surface, it will exercise but little friction upon any one part of it; long boxes are therefore preferable to short ones; and they offer an additional advantage, in being large enough to contain capacious reservoirs for oil, in which the shaft runs and thus greases itself.

If a shaft is very long and requires more than two or three bearings, it is difficult to set and preserve them in such accurate positions that they will always remain in line, and not give cause for jams and increased friction; boxes which pivot in the middle and adjust themselves to the shaft should therefore be used in such cases.

Bearings or shells have been made from numerous compositions of metals, of which brass and bronze are best known; but alloys which can easily be recast and furnish a hard shell, are generally preferred in paper-mills. They are usually named after their makers, and may be purchased at the hardware stores. The composition which is used for stereotype plates, answers also very well.

Bearings of such materials can be renewed at the mill; but the boxes should be of cast iron, with hollow spaces for their reception. Whenever a new shell is required, the box must be well cleaned out, an iron or wooden shaft, of exactly the same diameter as the one which it supports, fitted in, and the molten metal—any remaining openings having been closed with putty—poured through a hole left for this purpose.

Hard-wood bearings are frequently used, and even glass bearings have lately been introduced and promise success.

Whatever kind of bearings may be used, they must all be kept well oiled. Self-oilers have been invented for this purpose, many of which may be of great value in saving oil and labor; but every manufacturer should employ a careful and reliable man, whose business it is to see that every part of the shafting and machinery is well greased.

If a box becomes heated, the expedient of cooling it down by mixing flour of sulphur with the tallow or greasing oil is usually resorted to; but it will only be efficient if the cause, which will frequently be found to be a jam or a too closely-fitting box, has previously been removed.

306. Calculation of Speeds and Sizes of Pulleys and Cog-Wheels.—Every part of the circumference of two pulleys of different sizes, which is covered by one and the same belt, has the same speed; a pulley of twice as large a circumference or diameter than its mate can therefore make only one revolution while the smaller one turns twice, or the speed of the shaft of a pulley is inversely proportionate to its diameter; in other words, as the number of revolutions is to be greater or smaller, the diameter of the pulley must be smaller or larger in proportion.

The same rule holds good for cog-wheels which work together, and it is the basis for the calculation of their sizes.

If we have, for example, a pulley of 48 inches diameter upon a shaft, which makes fifty revolutions per minute, and wish to drive from it another shaft with a speed of one hundred and fifty turns per minute, or three times as much; we require for this driven shaft a pulley, the diameter of which is one-third of that of the driving one, or $\frac{48}{3} = 16$ inches.

SECTION VII.

Means of Transportation in the Mill.

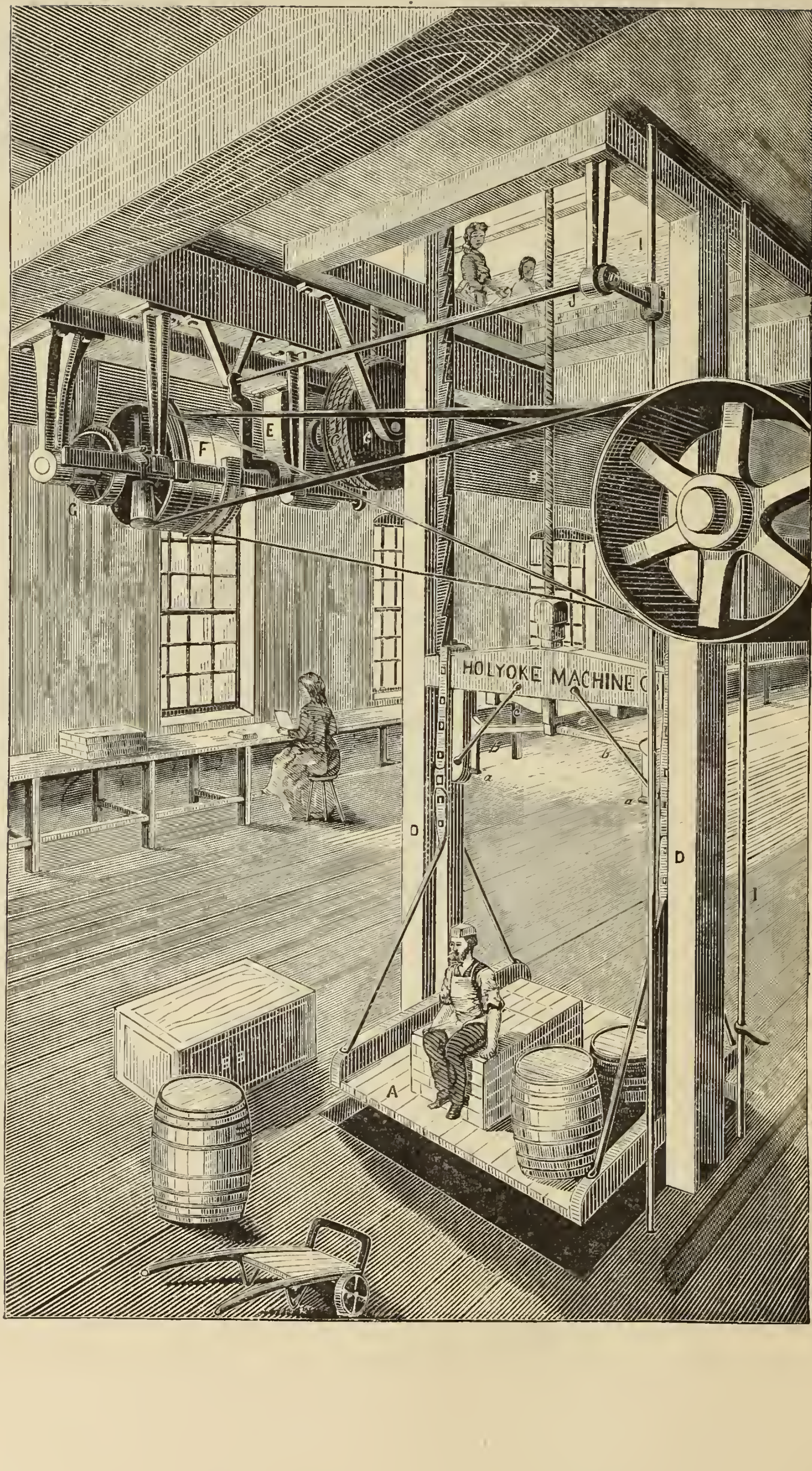
307. Trucks.—A great deal of raw material, half-stuff, white pulp and paper are constantly moved on the same floor, or from one story to another in paper-mills. All such transportation can be done in boxes running on rolls or trucks.

The pulp-boxes are usually 2 to 3 feet wide, 3 to 4 feet long, and 2 to 3 feet deep. The rolls are of cast iron, mounted on bolts or shafts carried by the two brackets of castings, which are bolted to the bottom of the box.

The larger the rolls are the easier will they run, but those of from 8 to 12 inches diameter and 2 inches face answer for most purposes. Four of them are required for a box, one in the middle of each side, and all parallel with the long sides. If the four rolls touched the ground at once it would be very difficult to turn the box, or even to move it in a straight line, unless the floor were perfectly smooth.

The cast bearings are therefore fastened in such a manner that the two rolls on the long sides project from the bottom of the box from $\frac{1}{2}$ to 1 inch more than the two on the short sides. When the box stands perfectly horizontal it rests only on the two wheels in the middle of the long sides, while the front and back ones remain at $\frac{1}{2}$ to 1 inch distance above the floor. This is accomplished by letting the latter into the bottom, or by putting a board of $\frac{1}{2}$ to 1 inch thickness between the bearings of the two side-wheels and the bottom.

Fig. 129.



It is thus impossible that the box should run on more than three wheels at one time, namely, the two side-wheels and either the front or rear one, according to the will of the man who pushes the box. Whenever a sharp turn is to be made, or an unevenness on the floor to be passed, the driver bears on or lifts the back end, so that the side-wheels alone remain on the floor, and there can be no difficulty in turning or moving the box in any desired direction.

308. Elevators.—A hoister, moved by pulleys and belts, and stopped and started at will, with a platform of such size that it can hold the largest boxes, ought to connect the different stories. Material or pulp can then be transported by means of the hoister and trucks from any one to any other point of the mill.

The size of the boxes must be suited to the requirements of each mill, and every hoister should be furnished with an arrangement which prevents it from falling to the ground if the rope or some other part should break.

The hoister represented in Fig. 129, as manufactured by the Holyoke Machine Company, Holyoke, Mass., may serve as an example.

The car A is suspended between two guide-posts D D, each having a toothed rack on the inner face, and is operated by a wire-rope B, which passes over a pulley at the top of the building, and thence to the winding drum C. The car is provided with two stop-dogs *a a*, connected with the draw-bar and spring *c* by the levers *b b*, which are instantly forced outward by the action of the spring, and engage with the toothed rack on the posts, in case the rope is broken, thereby preventing the fall of the car. Motion is communicated to the drum from the belts by a worm and gear, which are inclosed in an iron case, where they may be run in oil, and the wear usually attending such gearing, prevented.

The movement of the sliding shipper-bar is effected by its connection through the bell-crank J with the vertical rod I, which is provided with a handle at each landing, and, all being balanced, is moved with equal facility in either direction.

The car is stopped automatically on reaching the last landing, either ascending or descending, by coming in contact with a short arm fixed on the rod I.

The drum C and platform A can be moved in either direction, or stopped by means of an open and a cross-belt on the three pulleys F, the middle one of which is as wide as a belt, and keyed on the shaft, while the loose pulleys on each side are twice as wide as the belts. The two belts, being as far apart as the width of one belt, will always occupy one of the three desired positions on the pulleys; they will turn the shaft either to the right or to the left, or not at all.

It is frequently difficult to stop the hoister promptly, because the belts will not leave the tight pulley quickly enough, and a brake G is therefore provided.

The weight seen in Fig. 129 is attached to the end of a lever, which fits the upper part of the face of a pulley mounted on the driving-shaft. This lever carries a small pulley, which rests on the upper edge of the shifting-bar, and falls into a notch just before the belts leave the tight pulley entirely. The lever then bears on the friction-pulley, and acts as a brake, thus stopping the machine promptly, and holding it against any slight chafing of the belts.

SECTION VIII.

Heating and Ventilating the Mill.

309. Stoves and Steam-Pipes.—It is natural that we should frequently find mills heated in the same manner as dwellings, although stoves and their pipes are sources of danger and of idleness. Precisely as people do at home, so will the mill hands congregate around the stoves, whenever they have an opportunity to do so unobserved, and their work will be neglected in proportion. Small particles of the fuel, especially of coal and ashes, cannot fail to get into the pulp and paper, if they are admitted inside of the mill.

By heating with steam we create no fire-place, no useful room need be occupied, the heat can be started, stopped, and moderated by simply turning a valve, and fuel is saved. The pipes must be located on or beneath the floor, because heated air, being expanded and lighter than cold air, ascends.

Coils or bunches of wrought-iron pipes are frequently used, but they are expensive, while cast-iron ones, of about 4 to 6 inches diameter, answer the purpose in many cases as well. If they are suspended below the ceiling, openings must be left in the floor above, through which the warm air can enter.

Waste of steam is the principal danger which has to be guarded against. If live steam is used it should be conducted from the generator to the heating-pipes in small wrought-iron pipes regulated by valves. The heating-pipes should all be laid descending and connected in such a manner that the condensed steam cannot gather in bags or corners, but must return into the boilers; and if this cannot be done, the water should be withdrawn by means of steam-traps.

The outlet-valve can be regulated so that the steam will all be condensed, and the hot water thus obtained, if it cannot return directly to the boilers, should be forced into them, or used for some other operation, where it will save steam.

The steam, or rather the heat contained in it, will be more thoroughly exhausted in proportion as the surface of the pipes, through which it travels, is larger.

If the escaped steam from an engine is used for heating purposes, the pipes must be made capacious all through, to avoid contraction of steam and a consequent increase of the counter-pressure.

Whichever system may be adopted, none will heat the mill comfortably unless good care is taken that all the leaks in the building, and all unnecessary communication with the cold air outside, are prevented.

310. Ventilation.—We have not found any paper-mill provided with a thorough system of ventilation, although few buildings are more in need of it. The atmosphere of the different work-rooms is loaded with rag-dust, saturated with steam,

chlorine gas, and with the indescribable but well-known odor, disseminated by the steam which has been used for boiling rags, waste-paper, or straw, &c., and cannot fail to be injurious to the human system. Although paper-makers are wont to call it *healthy*, it will be admitted on reflection, that none but pure air can be so, not even chlorine, which serves as a purifier in very small quantities only.

Wet air, steam, dust, and chlorine are heavier than the atmosphere, and will collect on the floors of the work-rooms; it is therefore on the floor, and not at the ceiling, where ventilating flues should start.

Artificial ventilation is not required in summer-time, when the windows and doors may be kept open, and in winter it will be much assisted by a well-arranged system of heating. The brick or stone walls should be built with air-flues, which start from the floor of every room, where they may be regulated by means of registers, and reach the open air above the roof like ordinary chimneys. The lighter hot air will ascend to the ceilings and displace the impure moist air, driving it down towards the flues, through which it escapes, while a supply of fresh air should be admitted immediately below the heating-apparatus.

SECTION IX.

Lighting.

311. Oil.—The principal operations of a paper-mill require supervision only, and very little labor, and they are usually carried on during the night as well as the day, as the owners are generally desirous of utilizing the capital and water-power to the fullest extent. It is therefore of importance that the mills should be well lighted.

Since the discovery of petroleum in Pennsylvania, refined coal-oil has, on account of its low price and brilliant light, taken the place of nearly all other kinds of illuminating fluids, which were formerly burnt in lamps. To understand its nature, it is necessary to know how it is produced.

It is supposed to be the product of a natural distillation of bituminous coal on a large scale, and is found under ground, from 70 to 600 feet below the surface, in enormous quantities. Sometimes it is mixed with, or driven up by compressed gas, like water in an artesian well, but in most cases it has to be pumped up. Mr. David Murray, in a communication to the Albany Institute, 1862, gives the following description of the process of distillation:

"Much water is often pumped up with the petroleum, but separates from it on standing, the oil rising to the surface. The crude oil is put into large retorts of cast- or wrought-iron, and exposed to a heat of from 600 to 800 degrees, by which all the volatile ingredients are distilled, leaving 10 to 12 per

cent. of solid residue, constituting a sort of coke. The liquid thus obtained is comparatively colorless, though still retaining the odor of the crude oil. To separate various organic alkaloids and acids with which it is mixed, the distilled petroleum is agitated first with sulphuric acid and afterwards with a strong solution of soda or potassa; the sulphuric acid with its dissolved impurities being drawn off and the oil well washed with water before the addition of the alkali, it is afterwards again washed when the alkali has performed its function. The purified petroleum is now submitted to another distillation, but at first, at a temperature not exceeding 120 degrees, in order that only the more volatile carbo-hydrogens may be driven over, which are unsuitable for lamp-oil. These being condensed constitute what is now commonly called naphtha, which is used as a solvent for varnishes and caoutchouc, and for mixture with paints, a purpose which it answers as well as oil of turpentine, except for its offensive smell. It is unsuitable for lamps from its extreme volatility, its liability to smoke when burned, and the danger of explosion from the admixture of its vapor with atmospheric air. After the naphtha, which is equivalent to the benzine of coal-tar, has all come over, the heat is increased and the distillation continued, until the distilled liquid attains the specific gravity of 0.820. This is the part sold for lighting, and by far the most important product of petroleum. The quantity of it obtained varies greatly, sometimes not exceeding 30 per cent., sometimes amounting to 80 or 90. It is clear, and of a fine deep amber color, and answers admirably for lighting, yielding a brighter and purer flame than perhaps any other kind of lamp-oil. If the distillation be now continued, a darker and heavier product comes over, which, upon cooling, deposits paraffine. The part remaining liquid, which is too impure for burning, is employed for lubricating machinery."

The first products of distillation, being obtained at the lowest temperature, are the most volatile, and, as they cannot legitimately be sold for lighting, can be bought at very low prices. It is therefore the oil dealer's interest to mix as much of this volatile substance into the illuminating oil sold by him as the public will take.

A test has been established by which it can easily be determined, if an oil be suitable for illuminating purposes. Some of the oil is heated by means of an alcohol-lamp in the open tin cup of an oil-tester, and a lighted match is held over it at such height that the flame cannot reach the oil directly, but will only ignite it through the medium of its vapor as soon as it appears. The temperature shown at this moment by the thermometer fastened in the cup gives the *fire test* or the point at which the oil begins to evaporate.

The law has in some States fixed the fire test, below which illuminating oil is not permitted to be sold to the public, at 110 degrees Fahrenheit, but most oils will nevertheless be found below that standard.

If, during a hot night or in a highly heated room, such oil is either spilt or drawn from a barrel, vapor will immediately be formed, which, in contact with the light of a lantern or candle, will catch fire, and—like a fuse—communicate it to the oil, causing, perhaps, an explosion or a conflagration.

Different ingenious names are only the covers under which more or less volatile oils or benzine are sold, but they can easily be detected as such by the above test. Coal-oil of less than 110, or rather 120 degrees fire test, should not be used in paper-mills, or in the presence of any combustible matters.

Lamps of all kinds are a source of trouble; the smallest drop of water is sufficient to crack a heated glass globe; and breaks from this source can, in paper-mills,

where water and steam are always abundant, hardly be avoided. The glass also becomes moist from condensed steam, or black from the smoke of an imperfectly burning lamp, and thus obstructs the passage of light.

Besides the expense caused by breaks, repairs, wicks, and oil, a great deal of labor and attention are required to keep the lamps in order. Experience is necessary for the management of lamps, as well as of any other machine, however insignificant it may seem; and it is therefore best to let one careful person have charge of all of them.

312. Gas.—Gas burns without chimneys, wicks, or any preparation; it gives a uniform bright light, and is in every respect preferable to oil.

Many paper-mills, which are beyond the reach of gasworks, make their own gas, either from coal or from the residue of the distillation of petroleum or from coal-oil. A retort, a cleaner in which the gas is purified by lime, and a gasometer make up the equipment of such a gas factory, and the labor to be performed is very trifling.

Within late years gas-machines have come into use for the lighting of factories and residences, which are based on the easy evaporation of the volatile oils, the first products of the distillation of petroleum, which are so obnoxious in lamp-oil.

All of these machines consist of three parts, one of which contains a drum—immersed in water and constructed on the same principles as those in gas-meters—which is set in motion by a combination of a weight and gearing, similar to those used in old clocks. The second part is an evaporator, wherein the gasoline is presented in as fine a division or with as large a surface as possible, to the current of air, which comes from the first part; while the third part is only a miniature gasometer.

The mixture of air and hydrocarbons is conducted from this gasometer directly into the pipes and to the burners, and gives a splendid light. The pipes should be well protected against cold to prevent condensation.

These machines, and the gasoline with which they are fed, must be kept at a short distance from the mill, or at least in a stone cellar or vault, to which one reliable man only has access.

A strong reservoir of boiler iron may be buried on the hillside, or placed at some height above the machine, with which it should be connected by a pipe. Several barrels of gasoline may be emptied into this receiver and, the opening having been well closed again, the naphtha can remain there in perfect safely, feeding the machine through the connecting-pipe without ever being handled or even seen. If the receiver were hermetically closed, the gasoline could not be drawn off; a small pipe issues therefore from its top and extends to some place at a distance, where the air may enter without leaving room for any possibility of danger.

The two large mills of Messrs. Jessup & Moore, near Wilmington, Delaware, are lighted by means of gas-machines, located in small stone buildings, at a short distance.

We may mention here that some mills in the neighborhood of the oil regions

are so fortunate as to obtain from underground, through wells, a supply of gas, which is not only sufficient to furnish all their light, but also to heat the boilers and raise steam. Other manufacturers in the same regions have, since the accidental discovery of these wells, begun to *bore for gas.*

SECTION X.

Machinery.

313. Quantity and Quality.—A great deal of machinery used for the manufacture of paper has been described in the preceding pages; but it must be remembered that every mill requires only that portion of it which is suitable for its particular purposes. We may say that, as a rule, the quantity of machinery increases with the quality of the paper; a mill which produces 1 ton or 2000 pounds of wrapping-paper per day will, for instance, be found to be a much simpler and less extensive establishment than a mill which turns out such a quantity of fine paper.

As in every other branch of manufacturing, so in paper-mills has manual labor been superseded by water- and steam-power, and all efforts in that direction deserve to be encouraged; but, at the same time, it is not to be forgotten that every piece of machinery requires capital for its purchase, power, oil, and repairs while it is at work, and renewal when it is worn out.

That mill will therefore be most successful—all other conditions, especially the number of hands employed, being equal—which produces the same quality and quantity of paper with the least machinery.

Compact and judicious arrangement, and especially the good quality of the machinery, are essential. If poorly built, it will not only furnish bad work, but cause endless repairs and consequent stoppages. Money can hardly be squandered more extravagantly than in buying inferior machinery, when a comparatively trifling advance would procure a good article.

Manufacturers should purchase only from machinists who understand their business, and have both the will and the means to furnish good work.

A builder of machinery can easily economize, by reducing the quantity of material used in different parts, by substituting wood or cast iron for wrought iron, iron for brass or steel, by leaving some parts rough instead of planing or turning them, and by employing cheap help and tools. A high-priced machine may thus be found cheap when compared with one of the same size, but of different make, which was perhaps sold for much less.

In case of sudden breaks it is of great value to have a good machine-shop within easy reach of the mill, and thus to avoid the delays of distant transportation; to

encourage home industry, in the narrowest as well as in the fullest meaning of the word, is therefore—everything else being equal—the paper-maker's best policy.

Large mills find it to their advantage to have a small machine-shop of their own, and even those of moderate size find sufficient use for a forge, lathe, and drill, with the necessary tools.

A supply of lumber, taps, and dies for screws, wrought-iron pipes and fixtures, and a millwright with his tools should be on hand in every paper-mill.

SECTION XI.

Buildings.

314. Plans and Building-Materials.—The price of the different building materials and the quality of the paper which is to be made should decide the character of the buildings. The manufacture of the lowest and cheapest grades of paper does not justify the erection of costly houses, while to maintain the perfect cleanliness so essential for fine papers, nothing will be of as much assistance as substantial, well-lighted and constructed work-rooms, in the erection of which, however, not one dollar should be spent for the sake of appearance only.

A perfect plan of the mill and machinery, with all their details, must be made by a competent person before ground is broken for the foundation, and before any of the machinery is ordered, as it is much easier and cheaper to correct errors on paper than in stone and iron. Mills which might have been prosperous, have become failures because this has been neglected, and many thousands are often spent in remedying the evils of bad planning.

The water and steam which abound in paper-mills, are destructive to all kinds of wood. Iron and stone should therefore take the place of wood as far as possible, and if lumber must be used, only such kinds should be selected, which, like white oak, yellow and white pine, are able to withstand for a long time the influence of a moist atmosphere.

The latest and best-constructed New England writing paper-mills are solid three- or four-story brick buildings, with a separate two-story wing for the paper-machines.

The ground floor contains the drainers for bleached pulp, gearing, tubs for the preparation of animal size, stuff-chests, and sometimes the rag-boilers; the paper-machines, all the washing and beating-engines, and, wherever it is feasible, the rotaries, occupy the second floor. The third and fourth stories are divided into two parts, one of which, above the rag-boilers, contains the thrashers, cutters, dusters, sorting and store-rooms for rags, while the other, nearest to the paper-machine, is fitted up as a

finishing-room. All the available space on top of the building or the lofts, are used as drying-rooms for the surface-sized sheets.

In order to carry out a strict separation between the rag-department and the finishing-rooms and lofts, each division is sometimes supplied with a separate elevator.

The iron ladders which are fastened to the outside of these buildings as a means of escape for the employees in the upper stories, in case of fire, are a feature deserving of praise and imitation.

Every story carries machinery of some kind; the walls are therefore strong, and the floors, supported by strong iron girders and columns, are composed of 3-inch planks, covered with 1-inch flooring-boards above and $\frac{1}{2}$-inch flooring-boards below, or altogether $4\frac{1}{2}$ inches thick, and impregnable to dust.

The steam-boilers are located in separate buildings, but as near as possible to all the steam-consuming machinery.

315. Fire-Proof Paper-Mills.—The danger of fire deserves consideration in the construction of any mill, and is another reason for the substitution of stone and iron for wood wherever it is possible.

It pays probably best to build paper-mills perfectly fireproof, as alone the saving of all expense for insurance is in the United States sufficiently large to justify the increased outlay of such a construction, without taking the more substantial and permanent character of the buildings into consideration.

The new mill at Rockland, near Wilmington, Del., owned by Messrs. Jessup & Moore, of Philadelphia, has been built, at a cost of nearly half a million of dollars, entirely of stone and brick; it has iron roofs, brick and cement drainers and stuff-chests, iron and stone floors, and iron cutters and dusters in the rag-room, iron washers and beaters; in fact, there is hardly any wood used, excepting the 4-inch flooring-planks laid upon iron joists in the engine-, machine-, and finishing-rooms, all of which are situated in the second story, and can be flooded with water at a moment's notice.

We have seen mills burned to a worthless pile of rubbish, which had been considered and really were fireproof; but they had been filled with combustible material, raw and manufactured, which created such a heat that iron pillars were bent, and brick walls burst as if they had been glass.

It is therefore indispensable that separate store-rooms be supplied, and that no more stock than is necessary for one day's supply, or even less, should be allowed inside at any one time, if danger from fire is to be really avoided.

SECTION XII.

Location and Site.

316. Selection of a Country.—We observe, in casting a glance at the manufactories of all civilized nations, that perfection in any art is generally only acquired where the production of a certain class of goods has been the business of generations, handed down from one to another, and improved upon by each succeeding one.

The largest paper-mills are found, and the finest paper is made, in America as well as in Europe, in States and localities which are in no way more favorably situated than many others; they prosper, and thus invite the erection of more such mills in the same neighborhood, until it would seem to the superficial observer that by crowding together in such a way, and selling and buying necessarily in the same markets, they must be ruined through competition. Nevertheless they flourish, and are often able to undersell mills located in a country, which is less filled up with paper-mills, and which also furnishes a cheaper supply of raw materials.

It seems that a population of trained paper-makers, connected with the trade by family tradition, is, notwithstanding the substitution of machinery for hand-work, as valuable as ever. It is only natural that a mill, in which even the most trifling operation is conducted by men, who bring to their work not only their own, but also the experience of generations before them, should excel in every respect.

The skill and experience of such operatives will enable the manufacturer to produce from the same stock, and with the same means, a better grade of paper than is usually obtained.

Where paper-mills concentrate there will be found machine-shops, ready and able to furnish at short notice any piece of machinery which may be required, as well as manufacturers and dealers in all articles used by the paper-maker, who also make this branch a specialty, and improve in it constantly.

The different lines of transportation find it worth their while to make concessions to the trade, in order to secure the custom and head off competition.

The large number of mills also admits of such a division of labor, that every one of them may devote itself to the exclusive manufacture of only one kind of paper, and the dealers find it to their interest to assort the stock, so that they can supply each mill exactly with the quality it requires.

These advantages are frequently undervalued, although the facts show that they are often sufficient to make up for the higher prices which are paid for raw material and labor, as compared with isolated mills in countries where little paper is manufactured. The lower the grade of the paper the less skill is, with few exceptions,

required from the operatives; the paper trade sends therefore into countries which are devoid of the blessings of our art, as pioneers first wrapping-mills; they pave the way, and are followed by those for print and other medium grades, which make up the body of our army. The headquarters, or the seat of the manufacture of the finest papers, usually remains in the original settlements, or moves only very slowly, the price of fine papers being so high that they may be shipped to distant parts for a small proportion of their cost.

It is difficult to carry on paper-making in new countries, or in old ones devoid of factories, although it may be favored by low prices for raw material and high ones for paper; failures of the most promising undertakings of this kind are therefore not unfrequent.

Good management is the condition of success anywhere, but in a much higher degree with paper-mills, located far from machine-shops which are used to build paper machinery, with perhaps poor facilities for transportation, and surrounded by an unskilled population.

317. Site.—The selection of a site for a paper-mill is a matter of vital importance and must be done with great care.

It is supposed that nobody would embark in such an enterprise without having determined at least what quantity and kind of paper is to be made, and where it is to find a market; and a site must therefore be looked for within reasonable distance from that locality.

If, for instance, rag print-paper shall be made, and the market is a large city, it is desirable to locate as close to it as possible at a point where either rail or water communication, or both, can be had. A water-power is naturally first looked for, and if one can be obtained in such a location, which is permanent or sufficient during the whole year, with a mill site which is not exposed to floods, it is worth a considerable sum. From 60 to 100 effective horse-power are required for the manufacture of from about 2000 to 4000 pounds of paper from rags in twenty-four hours; but if imperfections, straw, wood, or other prepared fibres are used, smaller powers will be sufficient. A plentiful supply of wash-water is also to be provided for, and its purity is of so much greater importance as the paper is to be of better quality and color.

Sites which unite good water-powers, with an ample supply of pure wash-water, if located in proximity to the markets, are scarce and dear, and our choice is mostly confined to either steam-power near the city or water-power at a distance.

It is quite appropriate to consider in this connection the gradual depreciation of the water-powers and the causes thereof.

318. Depreciation of Water-Powers.—Woods are the regulators for our streams; they protect the ground by their foliage against the rays of the sun, and enable the water contained in it—by preventing a rapid evaporation—to flow out gradually, and to nurse the creeks and rivers during the hot seasons.

It is well known that woods are cooler than the surrounding cleared and cultivated soil, and when hot air loaded with moisture—clouds—comes within their in-

fluence, the lower temperature causes some of the moisture to condense and to fall down as rain. It has been found that, where woods or large numbers of trees have been artificially planted on prairie-lands, rain showers, before unknown, became quite frequent during the summer. The present sterility of the once fertile and prosperous countries of Eastern Asia, especially of the Holy Land, is attributed by the best authorities to the destruction of its trees.

The unusual often-repeated floods in the south of France, during the reign of Napoleon III, caused damage and loss of property to such an extent that something had to be done to prevent them. Millions were spent in rectifying the courses of rivers, but without the desired result, until at last the government undertook the replanting of trees on an enormous scale where the woods had years ago been cut down.

The wholesale destruction of the woods decreases constantly the value of our water-powers, and especially of those on short streams. The rains are no longer absorbed by millions of trees and by the protected soil below them, but run off nearly as fast as they fall, creating freshets, and leaving no filled reservoirs, except occasionally a lake, behind them, from which our rivers might draw a supply during the summer.

319. Comparative Value of Water and Steam-Powers.—The rental value of a constant water-power near the city or market is equal to the sum of money which would have to be spent for the production of the same power with steam in the same locality.

For a water-power at a distance, the cost of transportation of paper *from* and material *to* the mill must be deducted. About 2 tons of raw material, such as rags and chemicals, are required in a rag-mill, and about 4 tons in a straw print-mill, for every ton of white paper produced, without counting the fuel.

In many cases, where transportation is made costly by bad roads or want of railroad or water communication, this item is sufficient to reduce the value of the site to nothing. We even know of mills, situated in the country, which could be run by steam at the city or market with less money than is at present expended for railroad freight and teaming, while they are at the same time exposed to periodical floods and to scarcity of water. Such sites are worth less than nothing, unless they have other advantages by which these drawbacks may be offset.

Some mills buy all their rags from the peddlers or first gatherers in the surrounding country, and thus add the profits of the rag dealer to those of the manufacturer; others draw their supply of straw from the neighborhood; fuel and lime are perhaps cheaper than near the city; and one or several of these advantages combined may turn the scale in favor of the country.

If a mill is near the market the owner is enabled to be his own agent and to superintend the mill besides; and by saving the profits of the middle-men or commission merchants, he frequently realizes more than the most splendid but far-off water-power could make up.

The importance of a water-power is greater for some kinds of paper and stock than for others. If, for instance, waste-paper, which is gathered in large quantities only in the cities, is the raw material used, the power required is not very large, and a mill near the city may probably work it up at less cost with steam than one far off with a water-power. A good water-power is, on the other hand, nearly indispensable for a Manilla-paper mill, as the quantity of stock used and of paper made is small in comparison with the power which is required.

SECTION XIII.

Capital.

320. Cost of Paper-Mills.—Sufficient capital is one of the first necessities in any business. A paper-mill may have been built partly with borrowed money, or the means to carry it on may have been procured on credit, but their forthcoming must be assured before the first stone is laid.

The erection of paper-mills has frequently been undertaken with insufficient capital, based on estimates made by machinists, builders, or other interested parties, and the inability to provide the additional means, which were subsequently found to be required for their completion, or the procuring of a loan on ruinous conditions, has in many cases been the cause of failure and loss of all previous investments.

Even carefully made estimates of the *probable* cost of any buildings fall usually short of the *actual* expense, and the author, having been trusted with the erection of new paper-mills and the renovation of old ones, and being fully aware of this fact, has in every instance endeavored to calculate the prospective cost high enough, but his figures only served to confirm the experience of others—they were considerably too low.

The *probable* cost of new mills should be ascertained from the *actual* expense of other establishments, which have been built in a similar manner and under similar circumstances, and the means provided should be largely in excess of that sum, so that unforeseen difficulties can be met without embarrassment.

321. Working Capital.—If all the available capital has been absorbed by the erection of the mill, the manufacturer will be compelled to purchase his raw materials on credit, and to sell his paper for cash, or to consign it against advances to a commission house. He is thus embarrassed from the start, and finds himself compelled to deal exclusively through commission merchants, who naturally take the cream of the earnings of the mill for their money and labor.

If the paper-maker is lucky enough to make such a connection with a well-meaning, solid party, if he manages well, and understands his business, he will probably succeed against all odds, and make himself, in the course of time, financially

independent; but otherwise he must remain in a chronic state of poverty, or end with a failure.

The products of the mills are distributed to the public by the dealers, who form a necessary factor of the paper trade. But while the services of these middle-men cannot be dispensed with, the manufacturer should select those with whom he wishes to enter into business relations,—a freedom of action which he can only preserve by the possession of sufficient capital. If he is short of funds, he will be at the mercy of some one of their number, who makes the required advances.

322. Conditions of Success.—The capital invested should bear the right proportion to the value of the manufactured paper. A wrapping-mill should be built as cheaply as possible, while the best of material and labor should be employed in the construction of a mill for the manufacture of fine papers.

Although the price of labor is higher in the United States, the value of the production of paper-mills is here fully as large in proportion to the invested capital as in Europe, because the *relative* prices of building material, machinery, and paper are about the same. We have found from numerous observations in different countries that the following rules will apply everywhere.

The value of the products or sales of a paper-mill during one year, should never be less than an amount equal to the capital invested.

If the mill has been economically built, supplied with good machinery, and is well managed, its yearly sales may amount to twice as much as the capital, and we have even found some mills, making the better kinds of print and book-paper, which sold during one year three dollars' worth of paper for every dollar of their investment (exclusively of working capital). Such mills are nearly always prosperous; the proportion of sales to capital giving generally a very good measure of their success.

Economy of manufacture requires that a mill should make only one class of paper; machinery, buildings, stock, and labor can then be provided of such quantity and quality as to suit it exactly, and excellence in that particular branch can be better attained than if the grade of paper has to be constantly changed.

The more fully this system is carried out, or the fewer qualities and weights of paper are manufactured, the more will the whole mill assume the regularity of a machine, and, if it is otherwise well managed, pay good profits to the owners. The investment is reduced to the smallest possible sum, as only such buildings and machinery are put up, as are suited to the one kind of paper which is to be made. The quantity of stock on hand can be restricted to a few weeks' supply, or even to less, and the working capital will thus be limited to a very small amount.

Even the largest mills in the United States confine themselves as much as possible to the manufacture of one or a few kinds of paper, although they produce from 10 to 20 tons per day.

There is too much capital and labor employed in a paper-mill to permit it to stand idle for want of power. If the water-power is liable to give out or to become insufficient for any long period during the year, it is in most cases advisable to supply the deficiency by steam-power.

SECTION XIV.

Labor and Management.

323. Labor.—The cost of labor is only a small portion of the cost of making paper. From observations made in different countries and in mills, for fine as well as coarse paper, we are justified in stating *that the cost of labor amounts to not more than from ten to twenty per cent. of the market value of finished paper* in Europe as well as in America, or, to give an example, the wages of the operatives will amount to about $100 to $200 for every thousand dollars' worth of paper.

High wages stimulate the substitution of machinery for manual labor, elevate the working classes, and, considering that the ingenuity of man is fully equal to the task of replacing muscular power by that of steam and water, in proportion as the price of the former advances, cannot be otherwise than beneficial.

This theory is fully proved by the experience of the United States, where, as we have before stated, the value of paper bears about the same proportion to the cost of the manual labor actually employed in its manufacture as in Europe, although the price of labor is here nearly three times as high as there.

A location in the country has very little advantage over one near a city as far as labor is concerned, inasmuch as skilled labor commands the same wages almost everywhere, while the occasionally lower price of unskilled labor, at a distance from the centres of population, is often offset by the difficulty of procuring it at all.

324. Management.—The success or failure of a paper-mill can hardly ever be attributed to the price of labor, but depends very largely on its management.

We know mills with old and rather poor buildings and machinery to be more prosperous than others splendidly fitted up with the latest improvements, simply because the able management of the former not only makes up for its deficiencies, but also succeeds in producing a better article at the same expense than the latter.

We have seen the most stupid experiments tried in paper-mills, when a slight knowledge of chemistry would have prevented them, and saved a great deal of money. The manager of a paper-mill is often called upon to select machinery, order repairs, and generally to decide what is to be done, and should therefore have some knowledge of mechanical engineering and drawing.

The superiority of many goods of French and German manufacture over the English ones at the last Paris Exhibition has been attributed principally to the fact that nearly all French and German factories are managed by men who have been educated at polytechnic and other scientific schools, while this is not the case in England.

But, while we value a scientific education as a first class foundation, it must not be forgotten that it is practically unavailable, if not followed by that experience which can only be acquired by hard work and close application in the mills.

If a choice must be made between a man of science and one of experience, the latter deserves the preference, as he knows at all events what he has seen and done before, while the theorist will have to waste much money in learning by his own experiments what the paper-makers know from the experience of past generations.

We have the greatest regard for the traditions handed down from one paper-maker to another, because they represent a knowledge acquired by years of toil, which has stood successfully the test of time.

Through the progress in the arts and sciences and their application to our manufacture we have, however, been able to improve considerably on the old systems, and it is not too much to say, that a rational production of paper from the substitutes, such as straw, wood, &c., could not have been possible without their aid.

The manager of a paper-mill should have a knowledge of mechanical engineering, of applied chemistry, of commerce, and book-keeping, and above all must he thoroughly understand the process of making paper in all its details, however insignificant they may seem.

The quantity and quality of the labor performed by men being altogether dependent on the earnestness of purpose by which it is directed, it is necessary for the manager to secure the good will of the operatives.

Justice, kindness, and liberality never fail to be appreciated by the mass of the workmen, although there may be some exceptions, but their strongest efforts are only brought out when they find that the interests of the mill are identical with their own. Even the best men will do more work by the job than by the day; their labor is their capital, and they do not want to spend any more of it than the wages justify.

In mills, where only one kind of paper is made, and all efforts are directed to increasing the quantity, nothing will prove more effective than additional pay, given to all hands in proportion to their wages, for every 100 or 1000 pounds of paper made over and above the usual amount during a week or month.

If different grades of paper are manufactured, the additional pay may be proportionate to their total market value or to the profits of the mill.

The operatives are usually poor and depend upon their earnings to provide for their families; if their wages are paid only once per month they have to buy frequently on credit; and weekly payments, wherewith they are enabled to buy for cash and at lower prices, have therefore for many a purchasing value of from 5 to 10 per cent. more than monthly ones.

Experienced workmen are necessary for the success of a mill, and it is the manufacturer's interest to induce the operatives to make the neighborhood of the mill their permanent home. If a man once settles down, and buys a homestead, he will take a stronger interest in the affairs of the country, give more attention to the education of his children, and generally become more reliable and useful.

The first step to this end is *saving money.* If the workingman can only be once brought to save a part of his earnings he soon finds pleasure in doing so, and stops wasting his surplus for intoxicating drinks. We have induced men, who used to spend a large part of their wages in liquor, on whom temperance speeches and moral teachings had no effect, to save money, then to buy a homestead and improve it; they have become better husbands and fathers, and more valuable to the mill and to the community at large.

Manufacturers generally should assist their employés, rather to buy or build their own houses, than to lodge them in tenements. They will not only be benefited directly, but contribute thereby to the elevation of the following generation.

SECTION XV.

Statistics.

325. Statistics of the United States.—The ninth census of the United States, taken in 1870, gives the number of paper-mills in the different States and Territories, and the values of their products, as follows:

	No. of Establishments.	Products in Dollars.
Alabama,	1	124,000
Arizona,		
Arkansas,		
California,	2	89,700
Colorado,	1	2,250
Connecticut,	66	4,874,291
Dakota,		
Delaware,	1	78,000
District of Columbia,	1	81,520
Florida,		
Georgia,	3	184,023
Idaho,		
Illinois,	19	1,120,586
Indiana,	17	780,152
Iowa,	5	99,885
Kansas,		
Kentucky,	2	147,500
Louisiana,		
Maine,	12	1,214,607
Maryland,	26	948,710
Massachusetts,	95	12,687,481
Michigan,	11	499,392
Minnesota,	2	140,750
Mississippi,		
Missouri,	1	48,000
Montana,		
Nebraska,		
Nevada,		
New Hampshire,	32	1,673,595
New Jersey,	32	1,612,321
New Mexico,		
New York,	179	10,757,563
North Carolina,	5	166,240
Ohio,	44	4,010,483
Oregon,	1	28,000
Pennsylvania,	78	5,626,946
Rhode Island,	1	60,000
South Carolina,	2	79,000
Tennessee,	3	149,450
Texas,		
Utah,	1	4,330
Vermont,	12	318,510
Virginia,	4	244,268
West Virginia,	4	212,182
Washington,		
Wisconsin,	6	373,200
Wyoming,		
	669	$48,436,935

It will be seen from this statement that 669 paper-mills in the United States produced in 1870 nearly fifty million dollars' worth of paper.

General F. A. Walker, Chief of the Census Bureau, stated to the author, however, that the data obtained from the paper manufacturers have been less satisfactory than those received from any other branch of industry, and that the figures given above cannot be considered as very reliable.

326. Statistics of all Countries.—Mr. C. A. A. Rudel gives in his *Jahrbuch für Papier Fabrication*, second edition, Dresden, 1873, the following statistics concerning the manufacture of paper in all countries:

"The earth is populated by 1360 millions of human beings, but only 360 millions use for purposes of writing, printing, wrapping, &c., the *felted web*, which is incorrectly called *paper*."

The total yearly production amounts to 1800 million (German) pounds, which are distributed according to the following table:

COUNTRIES.	Number of Paper-Mills working with Paper-Machines.	Number of Paper-Machines.	Pounds of Paper made on Machines.	Number of Paper-Mills working by hand.	Number of vats for making Paper by hand.	Pounds of Paper made by hand.	Total weight of Paper manufactured, in German pounds.
Belgium, ...	19	39	44,600,000	5	8	400,000	45,000,000
Denmark, ...	5	9	7,100,000	1	2	100,000	7,200,000
Germany, ...	423	539	335,600,000	171	291	24,400,000	360,000,000
Austria, ...	130	186	139,200,000	84	123	4,800,000	144,000,000
France, ...	404	510	281,000,000	230	360	15,000,000	296,000,000
Greece, ...	....	....	....	...	....	....	....
Great Britain, ...	274	420	349,900,000	95	253	10,100,000	360,000,000
Italy, ...	67	100	91,600,000	49	145	4,400,000	96,000,000
Netherlands, ...	10	13	13,000,000	11	36	1,400,000	14,400,000
Norway and Sweden, .	20	28	26,200,000	8	20	800,000	27,000,000
Portugal, ...	16	20	11,100,000	8	22	900,000	12,000,000
Russia, ...	66	98	63,100,000	45	98	3,900,000	67,000,000
Switzerland, ...	30	39	19,500,000	8	12	500,000	20,000,000
Spain,.	17	21	13,800,000	122	272	12,200,000	26,000,000
Turkey, ...	....	....	....	1	3	100,000	100,000
Africa, ...	1	1	400,000	2	3	100,000	500,000
Brazil, ...	1	1	800,000	...	....	....	800,000
Canada, ...	2	2	1,000,000	...	....	....	1,000,000
Mexico, Peru, ...	....	....	....	...	....	....	....
United States, ...	467	634	317,000,000	100	150	6,000,000	323,000,000
Asia, Australia, . . .	....	....	....	...	....	....	....
	1,952	2,660	1,714,900,000	940	1,798	85,100,000	1,800,000,000

The total consumption of paper in different countries, and the consumption calculated per head of their populations, are given by Mr. Rudel, as follows:

COUNTRIES.	Total number of inhabitants—in millions.	Total consumption of paper—in German pounds.	Paper manufactured per head of the population — in German pounds.	Paper consumed per head of the population—in German pounds.
Belgium,	5.0	35,000,000	9	7
Denmark,	1.8	7,200,000	4	4
Germany,	40.0	320,000,000	9	8
Austria,	36.0	126,000,000	4	3½
France,	37.0	259,000,000	8	7
Greece,	1.5	800,000	...	½
Great Britain,	30.0	330,000,000	12	11
Italy,	24.0	96,000,000	4	4
Netherlands,	3.6	14,400,000	4	4
Norway and Sweden,	6.0	21,000,000	4½	3½
Portugal,	4.0	14,000,000	3	3½
Roumania, Servia, and Montenegro,	3.6	1,800,000	...	½
Russia,	67.0	67,000,000	1	1
Switzerland,	2.5	17,500,000	8	7
Spain,	26.0	26,000,000	1	1
Turkey,	27.0	13,500,000	...	½
Europe,	315.0	1,349,200,000	4½	4⅛
United States,	38.0	418,000,000	8½	11

COUNTRIES.	Total population—in millions.	The number of inhabitants who consume paper — in millions.	Total consumption of paper—in German pounds.
Africa,	190.	1.5	4,500,000
America,	84.	.....	....
Brazil,	11.	0.8	3,200,000
Canada,	4.0	0.8	4,800,000
Mexico,	9.0	0.6	2,200,000
Peru,	2.5	0.1	300,000
United States,	38.0	38.0	418,000.000
The Islands,	6.5	0.8	6,400,000
Asia,	760.	1.2	5,700,000
Australia,	4.5	1.2	5,700,000
Europe,	315.0	315.	1,349,200,000
	1360.	360.	1,800,000,000

These 1800 million pounds consist, according to the same authority, of

Writing paper,	300 million.
Printing paper,	900 "
Wrapping, hanging, colored paper, &c.,	400 "
Boards, cards, &c.,	200 "
	1800 "

The total consumption of paper is stated to be distributed among the different branches of human society in the following proportions:

Government offices,	from 10 to 12 per cent.
Schools,	" 10 " 12 "
Merchants,	" 12 " 14 "
Trades and manufactures,	" 6 " 8 "
Letters and individuals,	" 4 " 6 "
Printers and publishers,	" 50 " 56 "

The raw materials used in the manufacture of the 1800 million pounds of paper are derived from

2,000 million pounds of wool, taken from 218 million sheep, and furnishing 200 million pounds of rags,	100 million pounds of paper.
2,000 million pounds of cotton, which has been spun with the aid of 100 million spindles,	500 " " "
2,000 million pounds of flax and hemp, which have been worked into cloth,	400 " " "
200 million pounds of esparto, jute, agave, aloe, &c.,	100 " " "
400 " " straw,	100 " " "
400 " " wood,	200 " " "
750 " " chemicals, resin, oils, starch, colors, and clays,	300 " " "
3,000 million pounds of coal, which have been used as fuel,	
10,750 " " raw materials,	1800 " " "

The capital invested in the manufacture of these 1800 million pounds of paper is represented by the following amounts:

Cost of mills, in which paper is made on machines,	205,788,000 thalers,	or about	$154,341,000
" " " " " by hand,	8,512,000 "	"	6,384,000
Working capital,	55,700,000 "	"	41,775,000
Total capital engaged in the manufacture of paper,	270,000,000 "	(gold)	$202,500,000

The manual labor which is required for the production of 1800 million pounds of paper is performed by

Men in paper-mills, where paper is made on machines, .	76,000	
" " " " " by hand, . .	12,000	
		88,000
Women in paper-mills, where paper is made on machines,	152,000	
" " " " " by hand, .	6,000	
		158,000
Foremen and other employés, . .		4,000
Total number of persons engaged in the manufacture of paper,		250,000

The data given by Mr. Rudel are not quite correct, especially as far as the United States and Canada are concerned. The numbers given for the factories of these two countries are too low, and, while the United States can boast that there is no paper made by hand within their borders, Mr. Rudel credits them with one hundred hand paper-mills.

The tables will, however, be found to indicate, with some approach to accuracy, the comparative state of civilization attained by the population of the different countries, assuming as we do that

THE CONSUMPTION OF PAPER IS THE MEASURE OF A PEOPLE'S CULTURE.

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